US Army Corps
Of Engineers
Wilmington District

PHASE II DMMP Study
Upper Portion of Wilmington Harbor
Eagle Island Management Plan

Volume I

Wilmington, North Carolina

Final Report

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VOLUME I

PHASE II DMMP STUDY

UPPER PORTION OF WILMINGTON HARBOR

EAGLE ISLAND CONFINED DISPOSAL SITE

WILMINGTON, NORTH CAROLINA

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1.0 INTRODUCTION

The Eagle Island Confined Disposal Facility (CDF) is the primary disposal site for dredged material from the upper portion of Wilmington Harbor. An oblique aerial view of the site is shown on Photo 1 below.

Photograph 1. Aerial View of Eagle Island CDF

The upper portion of Wilmington Harbor consist of the reaches from Upper Big Island to just north of the turning basin at the upper end of the Federal Channel (See Figure 1). The continued long-term availability of the Eagle Island CDF for the disposal of dredged material is critical to the operations of Wilmington Harbor. This report provides an evaluation of the ability of the site to handle dredged materials from the upper portion of Wilmington Harbor for the next 20 years. In addition, management strategies to maximize the capacity of the site are provided.

1.1 OBJECTIVE

The Phase I Dredged Material Management Plan (DMMP) study (USACE 1997) conducted by the Wilmington District in 1997 evaluated the long term dredged material disposal capacity requirements for the maintenance dredging of Wilmington Harbor as well as the new work dredging being conducted as part of the harbor deepening project. The Phase I DMMP study identified the Eagle Island CDF as the primary disposal site for the dredged material from the upper portion of Wilmington Harbor. At the time of the study, the Eagle Island CDF had reached full capacity (USACE 1997) and significant improvements and dike raises were recommended to provide additional capacity. Subsequently, the U. S. Army Corps of Engineers, Wilmington District (Wilmington District) has initiated extensive rehabilitation of the dikes on the existing Eagle Island CDF and developed a preliminary plan for future dike raises at the site. To ensure that sufficient capacity will be available at the site for the next 20 years and that the most effective means of managing the site are employed, a detailed site management plan is required.

The objectives of this management plan for the Eagle Island CDF are: (i) to provide review and analysis of the projected dredged material disposal requirements for the upper portion of Wilmington Harbor and (ii) to provide a management plan to ensure that the maximum long term disposal capacity is achieved.

1.2 HISTORY

Since the early 1900's the upper portion of Wilmington Harbor has been dredged using a hydraulic cutterhead pipeline dredge with disposal of the dredged material in disposal areas located adjacent to the channel. The Eagle Island CDF, located on the peninsula between the Cape Fear and Brunswick Rivers south of Highway 17, has been the primary disposal site for dredged material from the upper portion of Wilmington Harbor.

The Eagle Island CDF is located on a 1,473-acre tract owned by the US Army Corps of Engineers. The property was acquired from the United States Marine Commission, which had condemned the property in the 1940's for use as part of a ship storage facility. The original property boundary for the site was defined by a series of rivers and creeks, most of which still exist and still serve as property boundaries for the site. However, Alligator Creek, which formed the northeast portion of the boundary has filled and is no longer discernable as a property boundary. Therefore, the 1948 Plat of the property and recent color aerial photography were used to approximate the property boundary of the site in the area originally delineated by Alligator Creek. The property boundary for the entire site is shown in Figure 2.

The CDF consists of approximately 880 acres of diked uplands, which originally was a tidal marsh and included several creeks. Over successive years of dredging, the creeks have been filled and the upland areas created. Historically the site was divided into two cells, a north and a south cell; however, as part of the recent improvement to the CDF, the north cell was subdivided into two cells of approximately equal size. Therefore, the existing Eagle Island CDF currently consists of three cells; Cell 1, Cell 2, and Cell 3 with diked areas of approximately 220, 260 and 260 acres, respectively.

1.3 SITE CONDITIONS

1.3.1 Topography and Soils

Eagle Island was built on a marsh with an original elevation of approximately 4 feet above mean sea level (msl), with a foundation of soft deposits extending down to approximately –38 feet msl (USACE 1995). Soil boring data indicate that the dredged material is over 20 feet thick in some areas and consist primarily of fine-grained sediments, though there are some pockets of sand located along the eastern side of the disposal area. Photographs 2 and 3 (following page) depict surface conditions at the CDF.

Photograph 2. South End of Cell 1, showing a localized pocket of sand on the eastern side of the CDF

Photograph 3. West Side of the CDF, Showing Outlet Structure

A major dike-raising project has been taking place at the Eagle Island CDF since 1998. At the completion of this phase of dike raising in 2000, Cell 1 had a top of dike elevation of approximately 27 feet and Cells 2 and 3 had dike elevations of approximately 25.5 feet. The average interior elevations of Cells 1, 2, and 3 were 14.3, 17.6, and 16.5 feet, respectively.

1.3.2 Environmental Setting

The Eagle Island CDF is located in the Tidewater region on the North Carolina Coastal Plain physiographic province. This area is generally of low relief with land surface elevation ranging from sea level to approximately 80 feet above sea level. This region consists of a multi-aquifer system of interbedded sand, silt, and clays, which overlay a fractured rock aquifer in most instances. The hydrogeologic units between the top of the Black Creek aquifer and the water table include the surficial Castle Hayne aquifer, the Pee Dee aquifer, and the Castle Hayne, Pee Dee, and Black Creek confining units. The Castle Hayne and Pee Dee aquifers are both semi-confined aquifers (USACE 1996 a).

Both the Castle Hayne and Pee Dee aquifers primarily show discharge to the Cape Fear River along the length of the shipping channel. It is possible that the flow trend may be interrupted locally by streams, lakes, ponds, groundwater withdrawal, or other natural or human activities. Data show an upward component of groundwater flow from the Pee Dee aquifer to the surficial Castle Hayne aquifer, and downward leakage from the surficial aquifer to the Pee Dee aquifer (Lautier 1996).

Recharge to the aquifers is primarily from precipitation, lateral inflow from adjacent areas, and inter-aquifer leakage. The areas of highest recharge are located in North Hanover County and eastern Brunswick County (USACE 1996 a).

The interior of Eagle Island is covered almost exclusively by common reed (*Phragmites australis*), a non-indigenous plant. Due to the highly disturbed nature of the site, species diversity is generally low. The most common species of mammals anticipated to occur are marsh rabbits (*Sylvilagus aqauticus*), hispid cotton rats (*Sigmodon hispidus*), and rice rats (*Oryzmys palustris*). Within the dikes of the CDF there have historically been areas of ponded freshwater that remain wet throughout the year. These areas are used by alligators, waterfowl, wading birds, and migrating shorebirds (USACE 1989). Other commonly noted species include the American coot (*Fulica americana*), great blue heron (*Egretta caerulea*), snowy egret (*Egretta thula*), grackels (*Quiscalus sp*.), and various sandpiper species.

2.0 DREDGING OPERATIONS

2.1 CHANNELS

The Eagle Island CDF is the primary disposal site for the upper portion of Wilmington Harbor that includes the following reaches of the Wilmington Harbor Navigation Channel:

- Upper Big Island;
- Lower and Upper Brunswick;
- Fourth East Jetty;
- Between Channel;
- Anchorage Basin;
- Cape Fear Memorial Bridge to 750 feet north of Hilton Railroad bridge; and,
- 750 feet north of Hilton Railroad Bridge to Northern extent of Federal channel.

Currently, the width of the navigation channel in this area is approximately 400 feet, except in the Anchorage Basin where it widens to about 1,200 feet at the southern end and then gradually reduces to 400 feet proceeding north. The sections of the upper portion of Wilmington Harbor located south of the Cape Fear Memorial are currently maintained at a project depth of 38 feet below mean lower low water (mllw). The section of channel from the Cape Fear Memorial Bridge north to the Hilton Railroad Bridge is currently maintained at 32 feet mllw. The section of the channel from the Hilton Railroad Bridge to the northern turning basin is maintained at 25 feet mllw. As part of the ongoing Wilmington Harbor Project deepening project, the channels in the harbor are being deepened and in some areas widened. Dimensions for the channel under the currently approved harbor-deepening project are provided in Table 1.

Table 1 - Authorized Channel Dimensions

Reach	Length (ft)	Width (ft)	Width at Widener or Basin (ft)	Depth (ft)	Required Overdepth for Rock (ft)	Allowable Overdepth for Dredging Variables (ft)	Total Allowable Dredging Depth (ft)
Upper Big Island	2,644	642		42	1	2	45
Channel Bend Widener			648	42	1	2	45
Lower Brunswick	8,682	400		42	1	2	45
Channel Bend Widener			823	42	1	2	45
Upper Brunswick	4,079	400		42	1	2	45
Fourth East Jetty	8,874	400	500	42	1	2	45
Between Channel	2,675	550		42	1	2	45
Anchorage Basin	8,643	400	1,200	42	1	2	45
Cape Fear Memorial Bridge to 750 ft N of Hilton RR Bridge	12,350	250 to 400	750	38	1	2	41
750 ft N of Hilton RR Bridge to PCS Nitrogen	5,500	250	800	34	1	2	37

Source: Wilmington District, Environmental Assessment, February 2000

2.2 DREDGE VOLUMES

2.2.1 Maintenance Volumes

Historical dredge records indicate that approximately 1,000,000 cubic yards (cy) of dredged material is removed from the upper portion of Wilmington Harbor on an annual basis. The majority of this material is from the Anchorage Basin reach (approximately 81%) and consists primarily of fine-grained silts and clays with some fine and medium sands. The volumes and physical characteristics of the sediments from the various reaches in the upper portion of the harbor are provided in Table 2. The volumes shown in Table 2 are the projected maintenance dredge volumes after the completion of the new work dredging and are based on historical dredge volumes plus a projected 10 percent increase (USACE, 1996)

Table 2 - Maintenance Dredged Material In Upper Portion Of Wilmington Harbor

Reach	Average Annual Maintenance Volume (cy)	Maintenance Schedule	Percent Gravel by Weight	Percent Sand by Weight	Percent Silt and Clay By Weight
Upper Big Island	2,600	4 years	2.0	94.0	3.0
Lower Brunswick	34,000	4 years	0.0	92.7	7.3
Upper Brunswick	18,100	4 years	0.0	57.0	43.0
Fourth East Jetty	25,900	2 years	0.0	80.0	20.0
Between Channel	61,500	yearly	0.0	80.0	20.0
Anchorage Basin	932,900	yearly	0.0	6.0	94.0
Cape Fear Memorial Bridge to 750 ft N of Hilton RR Bridge	70,600	3 years	10.0	55.0	35.0
750 ft N of Hilton RR Bridge to PCS Nitrogen	12,640	5 years	0.0	58.0	42.0

Base on the information in Table 2 is, approximately 216,000 cy of sand (19 %) and 935,000 cy of mud (81 %) are dredged from upper portion of Wilmington Harbor per year.

2.2.2 New Work Volumes

In addition to the maintenance material, the Wilmington District intends to dredge approximately 6.6 million cy of new material from reaches in the upper portion of the harbor as part of the Wilmington Harbor deepening project. This portion of the project is anticipated to take approximately 3 to 4 years and is scheduled to start in the fall of 2002. The volumes of material to be dredged from the various reaches in the upper portion of the harbor are included in Table 3. The new work material from the Upper Big Island reach (approximately 600,000 cy) will be transported offshore for disposal; therefore, it will not be included in the remaining evaluation. The new work material from the other reaches (approximately 6,000,000 cy) will likely be placed in the Eagle Island CDF.

The new work material will consist of silts, clays, sand, gravel, and rock. The anticipated rock quantities and overburden quantities are also included in Table 3. Overburden is material above the rock but below the depths currently dredged. While a detailed evaluation of the quantities of the various types of sediment in the overburden has not been performed, a review of the available core logs from these reaches indicate that approximately 50 percent of the material is sands and 50 percent is fine-grained material (consolidated clays).

Table 3 - New Work Dredged Material In Upper Portion Of Wilmington Harbor

Reach	New Work Overburden (cy)	New Work Rock (cy)	Total New Work (cy)
Upper Big Island	527,580	99,100	626,680
Lower Brunswick	742,870	6,530	749,400
Upper Brunswick	507,370	3,730	511,100
Fourth East Jetty	963,329	15,100	978,429
Between Channel	187,650	28,430	216,080
Anchorage Basin	889,533	405,020	1,295,553
Cape Fear Memorial Bridge to 750 ft N of Hilton RR Bridge	990,000	405,800	1,396,000
750 ft N of Hilton RR Bridge to PCS Nitrogen	859,748	45,077	904,825

2.2.3 Projected 20-Year Dredge Volumes

Based on the proposed new work dredging volumes and the anticipated maintenance dredge volumes, a schedule of the anticipated dredge volumes for the next twenty years has been developed and is provided in Table 4, on the following page. This projection includes a 50% increase in maintenance dredge volume in the dredging event immediately after the initial deepening. The dredge volume for the second dredge event after deepening includes a 25% increase in maintenance volume. After that, maintenance dredging is anticipated to stabilize at an annual volume approximately 10% greater than the pre-deepening dredge volume (this is the volume shown in Table 2).

2.3 DREDGE METHODS

2.3.1 Dredging and Disposal of Maintenance Material

Dredging in the upper portion of Wilmington Harbor is currently conducted using a hydraulic cutterhead dredge. Hydraulic cutterhead dredges slurry the in-situ material using a rotating cutterhead and then pump the slurry via pipeline to the Eagle Island CDF. The dredging process typically entrains several volumes of water for each volume of in-situ sediment, creating a slurry ranging from approximately 5 to 15 percent solids by weight. Once the slurry is placed into the CDF (typified in Photo 4), the solids begin to settle out of suspension. Coarse-grained material such as sands settle out of suspension rapidly while the fine-grained fraction of the slurry takes considerably longer. The result is a gradation of material across the disposal cell with the coarse grained material being located near the dredge pipe discharge point and the material becoming progressively finer approaching the discharge weirs.

Table 4 – Dredge Volumes

Dredge Window	Upper Big Island	Brunswick Lower			Brunswick Upper			Fourth East Jetty			Between Channel			Anchorage Basin		
(Calendar Years)	Maint.(cy)	Maint.(cy)	New Work		Maint.(cy)	New Work (cy)		Maint.(cy)	New Work (cy)		Maint.(cy)	New Work (cy)		Maint.(cy)	New Work (cy)	
			Overburden	Rock		Overburden	Rock		Overburden	Rock		Overburden	Rock		Overburden	Rock
Base	9,636	123,600			65,800			47,100			55,900			848,000		
00-01								47,100			55,900			848,000		
01-02											55,900			848,000		
02-03			742,870	6,530		507,370	3,730	47,100	605,303	9,488	55,900			848,000		
03-04	14,454	185,400			98,700				358,026	5,611	55,900	187,650	28,430	847,000	889,533	406,020
04-05								70,650			83,850			1,270,500		
05-06											69,875			1,058,750		
06-07								58,875			61,500			932,900		
07-08	12,045	154,500			82,250						61,500			932,900		
08-09								51,800			61,500			932,900		
09-10											61,500			932,900		
10-11								51,800			61,500			932,900		
11-12	10,600	136,000			72,400						61,500			932,900		
12-13								51,800			61,500			932,900		
13-14											61,500			932,900		
14-15								51,800			61,500			932,900		
15-16	10,600	136,000			72,400						61,500			932,900		
16-17								51,800			61,500			932,900		
17-18											61,500			932,900		
18-19								51,800			61,500			932,900		
19-20	10,600	136,000			72,400						61,500			932,900		
20-21								51,800			61,500			932,900		
Maintenance	58,299	747,900			398,150			586,325			1,299,825			19,713,750		
Overburden			742,870			507,370			963,329			187,650			889,533	
Rock				6,530			3,730			15,099			28,430			406,020

Table 4 – Dredge Volumes (continued)

Dredge Window	Cape Fear Mem. Bridge to Point 750' above Hilton RR Bridge			750' above Hilton RR Bridge to PCS Nitrogen			Total	Total	Total	Total	Dredge Window
(Calendar Years)	Maint.(cy)	New Work (cy)		Maint.(cy)	New Work (cy)		Maint.(cy)	Overburden (cy)	Rock (cy)	New Work (cy)	Total (cy)
		Overburden	Rock		Overburden	Rock					
Base	192,500			57,500							
00-01							951,000	0	0	0	951,000
01-02							903,900	0	0	0	903,900
02-03							951,000	1,855,543	19,748	1,875,291	2,826,291
03-04							1,201,454	1,435,209	440,061	1,875,270	3,076,724
04-05		990,000	405,800				1,425,000	990,000	405,800	1,395,800	2,820,800
05-06	288,750				859,748	45,077	1,417,375	859,748	45,077	904,825	2,322,200
06-07							1,053,275	0	0	0	1,053,275
07-08				86,250			1,329,445	0	0	0	1,329,445
08-09	240,625						1,286,825	0	0	0	1,286,825
09-10							994,400	0	0	0	994,400
10-11							1,046,200	0	0	0	1,046,200
11-12	211,800						1,425,200	0	0	0	1,425,200
12-13				71,875			1,118,075	0	0	0	1,118,075
13-14							994,400	0	0	0	994,400
14-15	211,800						1,258,000	0	0	0	1,258,000
15-16							1,213,400	0	0	0	1,213,400
16-17							1,046,200	0	0	0	1,046,200
17-18	211,800			63,200			1,269,400	0	0	0	1,269,400
18-19							1,046,200	0	0	0	1,046,200
19-20							1,213,400	0	0	0	1,213,400
20-21	211,800						1,258,000	0	0	0	1,258,000
Maintenance	1,376,575			221,325			24,402,149			6,051,186	
Overburden		990,000			859,748			5,140,500			
Rock			405,800			45,077			910,686		
										Total Volume	30,453,335

Photograph 4 - Delivery of Hydraulic Dredge Materials to Eagle Island

The fine-grained material undergoes a zone settling process characterized by the formation of a layer of "clarified" water on the surface of the sediment. The process of the suspended sediments in the slurry falling out of suspension is also referred to as sedimentation. The clarified water is discharged through the weirs and the dredged material remains in the CDF. At this stage of the process, the dredged material has a very high water content and a mayonnaise-like consistency.

Once the surface water is removed from the dredged material in the CDF, the surface of the material begins to dewater and dry. Dewatering the dredge slurry is most commonly accomplished through natural settling, desiccation, and evaporative drying. For fine-grained dredged material, the top foot or two of material will dry and consolidate creating a crust on the surface of the material. The crust creates a barrier to moisture, which limits the drying and consequently the consolidation of the dredged material below the crust.

2.3.2 Dredging and Disposal of New Work Material

As discussed previously, the new work dredge material consists of rock and overburden. While the dredge contractors will be allowed to use a variety of dredging techniques, it is anticipated that in areas with little or no rock, the dredging will be performed with a large (possibly 30-inch) hydraulic cutterhead dredge. In areas with rock, the most likely technique will be to blast the rock and then use a large hydraulic cutterhead dredge to remove the overburden and the blasted rock at the same time.

While the dredged material is permitted for ocean disposal at the Wilmington Harbor Ocean Dredged Material Disposal Site (ODMDS), it is anticipated that the material will be pumped directly to Eagle

Island CDF for disposal. As with the maintenance material, the coarse grained material will fall out of suspension quickly near the discharge pipe creating piles of material over time. This could be problematic for those areas where rock will be dredged. The rock will pile up rapidly at the mouth of the pipe and it will likely be necessary to take steps to frequently move the pipe or spread the pile.

The new work material will also include a significant portion of fine-grained material, some of which may be a tight, stiff clay. It is anticipated that some of the material will fluidize and behave in a manner similar to the fine-grained fraction of the maintenance material. Some of this material may not be fluidized and will be deposited in the disposal areas as clay balls. The amount of material that is deposited in the CDF as clay balls will be highly dependent on the type of material, the dredge equipment used, and the pumping distance.

3.0 SHORT-TERM DISPOSAL REQUIREMENTS

3.1 GENERAL

If hydraulic dredging operations are undertaken, the dredge will pump a slurry into the CDF. The design of the storage basin must provide the following for the slurry:

- capacity for initial storage;
- surface area for zone settling (sedimentation); and,
- sufficient retention time of water to allow settling of solids.

These design requirements are primarily determined by the settling characteristics of the dredged material. Methods for developing a disposal area design that meet these requirements are discussed in the following sections.

3.2 SETTLING CHARACTERISTICS

3.2.1 General

As discussed in the preceding section, the majority of the maintenance-dredged material from the upper portion of Wilmington Harbor consists of silts and clays. During dredging, the in-situ sediments are mixed with water creating a slurry that is pumped into the disposal basin. How the sediments settle out of suspension once the slurry is placed into the disposal area is critical in designing the disposal area. The settling characteristics are dependent on several factors including the type of dredged material, the initial concentration of the slurry, and the salinity of the water at the dredge site.

3.2.2 Column Settling Tests

To evaluate the settling characteristics of the dredged material, Column Settling Test's (CST's) were performed on the dredge material in accordance with USACE protocols (USACE EM 1110-2-5027). The CST is intended to simulate the settling of the solids in the dredge slurry after it is delivered to the CDF. Ten samples of maintenance material were collected from the Anchorage Basin for the CST's and determination of the physical characteristics of the *in situ* material. The sampling, testing procedures, and the results are discussed in detail in the supporting documentation describing laboratory testing (Volume V). CST's were performed only on the maintenance material and not the new work material.

Full CST's were performed on four of the samples, CST's 1, 2, 4 and 5. These samples were chosen because they are representative of the sediments with the highest percentage of fine-grained material (97% for CST 2) and the lowest percentage of fine-grained material (70% for CST 5). Because of the high percentage of fine-grained material in CST-2, the CST-2 column settling test results likely represent the worst case scenario in terms of settling characteristics of the material.

3.3 DESIGN CRITERIA

3.3.1 Capacity for Initial Storage

In design of the disposal area, the first consideration is providing sufficient volume for the solids that settle out of suspension after the slurry is placed in the CDF. The volume of this material will be highly dependent of the characteristic of the dredged material. Fine-grained dredged material will “bulk” and occupy significantly more volume than the volume of the material *in-situ*. Conversely, sands will bulk very little and occupy approximately the same volume in the CDF as their volume *in situ.* The volume required for the dredged material from a particular dredging event is referred to as the initial storage volume and can be calculated using the following formula:

$$V_f = V_i \left[\frac{e_o - e_i}{1 + e_i} \right] + V_i + V_c$$

Where,

V_f	=	final volume of material after dredging, cubic yards
V_i	=	*in situ* volume of fine-grained material, cubic yards
V_c	=	*in situ* volume of coarse grained material (sand), cubic yards
e_o	=	average void ratio of the dredged material in the disposal basin at the completion of the dredging operations
e_i	=	average void ratio of sediments in-situ

The void ratio of the dredged material in the disposal basin, e_o, is determined from the results of the column settling test. The *in situ* void ratio is determined from the physical analysis of the sediments. Dividing the volume of the dredged material after dredging by the volume of the material *in situ* gives a bulking factor for the dredged material.

3.3.2 Surface Area Required for Zone Settling

Design of the disposal area must also ensure that there is enough surface area in the disposal area to allow the zone settling process (sedimentation) to produce a sufficient volume of clarified water that can be discharged through the weirs. The volume of water to be discharged needs to be equal to or less than the volume of the slurry pumped into the CDF by the dredge. The surface area required for zone settling can be estimated using the following formula:

$$A_z = \frac{3600 Q_i}{V_s}$$

where:

A_z	=	surface area in the CDF required to achieve zone settling, square feet
Q_i	=	influent flow rate in ft^3/second
3600	=	conversion factor for hours to seconds

V_S = zone settling velocity at influent solids concentration, ft/hr

The zone settling velocity, V_S, is determined from the results of the CST, and the influent flowrate is dependent on the size dredge used and the pump rates.

Once the surface area has been determined, it is adjusted by the Hydraulic Efficiency Factor (HEF) to compensate for hydraulic inefficiencies in the containment area:

$$A_{dz} = \frac{A_z}{HEF * 43,560}$$

where

A_{dz} = acreage required to achieve the necessary zone settling
HEF = hydraulic efficiency factor (percentage)

The hydraulic efficiency factor can be determined for a specific site using dye tracer studies or estimated with the following equation:

$$HEF = 0.9\left[1 - \exp\left(-0.3\frac{L}{W}\right)\right]$$

where L/W is the length to width ratio of the disposal basin. It is possible to increase the hydraulic efficiency of the site through the use of interior spur dikes that serve to effectively create a higher L/W ratio.

3.3.3 Removal of Solids From the Discharge

The clarified surface water formed by zone settling (sedimentation) typically has residual solids that slowly settle out of suspension through flocculation. The amount of solids in the clarified water is highly dependent on the time the water is allowed to remain in the disposal basin (referred to as residence time). The amount of residence time required will depend on the water quality restrictions on the discharge from the disposal basin and can be estimated based on the results of the column-settling test.

Current North Carolina regulations for the discharge from a CDF require that the discharge meet a turbidity water quality criteria of 25 Nephelometric Turbidity Units (NTU's) within a "specified" mixing zone (State of North Carolina, General Certification 16). However, the existing guidance for assessing the water quality of the discharge is based on the total suspended solids (TSS) in the discharge, not the turbidity. There is no universal correlation between TSS and turbidity, and therefore, site-specific correlations have to be developed. For this site, samples collected from the CST were analyzed for both TSS and turbidity and a correlation of TSS = 1.1*NTU + 19.1 was established with a regression factor of 0.7. Plots of the data are provided in Figure 3. As shown in Figure 3, there is one TSS value (155 mg/l) that is significantly different from the other and appears to be spurious. If this value is removed, the correlation becomes TSS = 1.1*NTU + 17.0 with a regression factor of 0.9 (Figure 4). Using the later relationship, the TSS corresponding to 25 NTU is approximately 43.5 mg/l. Given that the water quality requirements for the discharge from an upland disposal area allow for the use of a mixing zone, it was assumed that a 2X dilution of the effluent could readily be achieved; and, therefore, a suspended solids concentration of 87 mg/l would be acceptable in the discharge. This value was used as the maximum limit of TSS in the effluent to meet the water quality requirements

Using the methodology in the USACE's guidance document (EM 1110-2-5027), the ponding depth required to meet the water quality requirements can be estimated based on the minimum residence time, disposal area size, and input rate. The calculation are based on the following equation:

$$H_{pd} = \frac{TQ_i}{A_{df}(12.1)}$$

where:

H_{pd}	=	average ponding depth required to achieve target water quality, feet
T	=	minimum mean residence time
Q_i	=	average inflow rate, cubic feet per second
A_{df}	=	surface area of the CDF, acres
12.1	=	conversion factor for acre-feet per cubic feet per second to hours

The minimum mean residence time is calculated based on the results of the CST and the target water quality requirements for the discharge. The hydraulic efficiency factor is used to adjust the residence time to account for the hydraulic inefficiencies in the disposal area.

3.3.4 SETTLE Model

To facilitate the process of evaluating various design alternatives of CDF's, the USACE has developed a numerical model, SETTLE, which is based on the mathematical functions, described previously. The model allows the user to quickly assess how changes to various design parameters will effect the operations of the CDF. Since the size of the footprint of the existing Eagle Island CDF is fixed, the analysis consisted of varying the other input parameters to determine what the constraints on the CDF design and operations would be.

The input parameters required by the SETTLE model are summarized below:

- <u>Results from the CST</u> – Data on the water-sediment interface height as well as results of the TSS analysis.
- <u>Dredge volume</u> – The *in situ* volume of the material to be dredged
- <u>Physical characteristics of the dredge material</u> – The percentage of silts and clays, the in-situ water content, and specific gravity of the dredged material.
- <u>Dredge operations</u> – Influent discharge rate, influent solids concentration, pipe size, hours dredged per day, days dredged per week, dredge production rate, and total days to complete the job.
- <u>Dimensions and operational considerations of the CDF</u> – The interior acreage of the CDF, the dike heights, the required freeboard and ponding depths, depth of withdrawal, percentage of area ponded, and hydraulic efficiency of the disposal area.
- <u>Water Quality Criteria</u> – The maximum allowable TSS in the discharge from the CDF.

Results of the SETTLE model include the following information:

INITIAL STORAGE

- <u>Minimum storage area (acres)</u> – The minimum number of acres required for the initial storage for the given dike elevation, ponding, and freeboard requirements.

- Required storage volume (acre-feet) – The minimum volume required for initial storage of the dredged material in acre-feet.
- Minimum dike elevation (feet) – The minimum dike elevation required for the given acreage to obtain the necessary volume for the initial storage. Value also includes the input freeboard and ponding depth.
- Minimum depth of storage (feet) – The depth of the settled solids in the CDF at the completion of the dredge operations
- Maximum influent flow rate (cubic feet per second) – The maximum discharge rate of the effluent into the disposal basin.
- Maximum production rate (cy/hr) – The maximum rate at which the in-situ material can be placed into the CDF.
- Minimum disposal period (days) – The minimum number of days required for the dredging
- Max *in situ* volume (cy) – The maximum volume of material that can be put in to the CDF during one dredging event.

ZONE SETTLING

- Minimum interior area (acres) – The minimum number of acres within the CDF required to achieve zone settling.
- Minimum ponded area (acres) – The minimum number of acres that will be ponded to achieve zone settling.
- Maximum Influent flow rate (cubic feet second) – The maximum rate at which slurry can be pumped into the disposal basin and still achieve the required zone settling rate.

DISCHARGE WATER QUALITY

- Minimum interior area (acres) – The minimum area within the CDF required for the effluent to meet the water quality criteria for TSS
- Minimum ponded area (acres) – The minimum ponded are within the CDF required for the effluent to meet the water quality criteria for TSS
- Minimum ponded volume (acres-feet) – The minimum volume in acre-feet required for the effluent from the CDF to meet the water quality criteria for TSS
- Minimum mean residence time (hours) – The minimum time that the effluent needs to be retained within the CDF to meet the water quality criteria for TSS
- Minimum depth of ponding (feet) – The minimum ponding depth that would be required for the input acreage to meet the water quality criteria for TSS
- Maximum influent flow rate (cubic feet per second) – The maximum rate at which slurry can be pumped into the CDF and the CDF discharge meet the water quality criteria for TSS
- Effluent solids concentration (mg/l) – The estimated TSS of the discharge based on the various input parameters.

Using the results of the SETTLE model, it is possible to determine what the limiting factors for the design of the disposal basin will be.

3.4 DESIGN REQUIREMENTS

3.4.1 Maintenance Dredging

The design requirements for the disposal of 1,000,000 cubic yards (cy) of maintenance material in the Eagle Island CDF were evaluated using the SETTLE model. Input data was based on the results of the column settling tests, the physical analysis of the *in situ* material, and the 1998 and 1999 dredge records. Based on the analysis of the dredge records it was assumed that the maintenance dredging would be performed using an 18 inch dredge pumping 14 hours a day 5 days a week with an average production rate of 612 cy/hr. The total time required to complete dredging was approximately 160 days. It should be noted that using this input and the *in situ* moisture content of the material, the SETTLE model estimates that the resulting solids content of the dredge slurry is less than 5 percent weight by volume. While this value is low compared to typical dredge slurry solids concentrations of 10 to 15 percent weight by volume, it is not unreasonable given the high water content of the *in situ* material.

The estimated concentration of the solids in the discharge water from the CDF was evaluated using the SETTLE model and the column settling test results for both CST-2 and CST-5. To achieve the targeted water quality value of 87 mg/l, the estimated residence time based on the results of CST-2 are significantly greater than the residence times based on the results of CST-5.

The results of the analysis indicate that all of the cells at Eagle Island meet the acreage requirements for the zone settling process to occur as long as the total time for the maintenance dredge project is not less than approximately 100 days. Based on historical dredge records, a total dredge time of less than 100 days is unlikely.

The initial storage requirements are determined by the bulking factors, which are determined from the results of the SETTLE model. Bulking factors for the dredged material were calculated using the results of CST-2 and CST-5. Assuming a dredging time of 160 days, the estimated bulking factor for the dredged material based on the results of CST-2 was 1.4. The bulking factor estimated from the results of the CST-5 was 1.3. For design purposes, a conservative overall bulking factor of 1.5 was assumed.

Once the required initial storage volume is determined, the various factors that will effect residence time have to be evaluated. These include the size of the disposal area, hydraulic efficiency of the site, rate of dredging, and depth of ponding. Given that the sizes and configurations of the cells at Eagle Island are essentially fixed, the primary options for increasing residence time are decreasing dredging rates or increasing ponding depths. Since reducing dredging rates increases costs, the preferred alternative for increasing residence time is increasing ponding. Therefore, the SETTLE analysis focused on the ponding depths required to achieve the targeted TSS concentration in the discharge. Analysis using the CST-2 data indicated that ponding depths of approximately 6.5 feet would be required. Analysis based on the CST-5 data indicated that ponding depths of only approximately 2 feet would be required. For purposes of this evaluation, a ponding depth of 4 feet was assumed. Historically, ponding depths at Eagle Island have ranged from 2 to 4 feet which compares well with the recommended 4-foot ponding.

3.4.2 New Work Dredging

As discussed previously, CST's were not conducted on the new work material. Therefore, a detailed analysis of the settling properties of the new work material is not possible. However, based on the type of material to be dredged, certain assumption can be made. The new work material will consist of clays, silts, sands, gravel, and rock. With the exception of the silts and clays, it can reasonably be assumed that the bulking of the material will not exceed 20 percent of the *in situ* volume. The amount that the silts and clays bulk is uncertain and will be determined by the stiffness of the material and whether or not it is slurried in the dredging process or comes into the disposal basin primarily as clumps and balls. If the silts and clays come in as clumps and balls, the bulking factor will remain relatively low. Conversely, if the silts and clays are completely slurried by the dredging process, the bulking factor would increase. Given the difficulty in predicting the behavior of the silts and clays, a bulking factor of 1.25 for the new work is recommended.

Based on the high percentage of coarse-grained material in the new work dredged material, the formation of clarified water is not anticipated to be a significant problem. However, due to the anticipated use of very large hydraulic dredges, water quality requirements for the discharge may be difficult to achieve. The large dredges discharge such tremendous volumes of water into the disposal basin that the residence time of the water in the basin is greatly decreased. In areas with significant quantities of silts and clays, this may result in high concentrations of suspended solids in the discharge.

For purposes of evaluating the short-term storage requirements, a ponding depth of 4 feet has been assumed. However, careful monitoring of the water quality is recommended. Furthermore, for the initial new work dredging projects, it is recommended that the cells being used for the disposal of the material have the ability to increase the ponding height several feet above the recommended 4 feet. This will reduce the possibility of having to reduce the dredge production rate.

3.4.3 Yearly Short Term Storage Requirements

Using the bulking factor and the ponding depths developed from the SETTLE model it is possible to generate the required yearly storage requirements for the anticipated dredge activities. The bulked volume of dredged material and the required ponding depth for each year for both the maintenance and new work material are summarized in Table 5.

Table 5 - Volume of Dredged Material Per Year

Year	MAINTENANCE			NEW WORK		
	In Situ Vol (cy)	Bulked Vol (cy)	Required Ponding Depth (ft)	In Situ Vol (cy)	Bulked Vol (cy)	Required Ponding Depth (ft)
2000	951,000	1,426,500	4	0	0	
2001	903,900	1,355,850	4	0	0	
2002	951,000	1,426,500	4	1,875,291	2,344,114	4
2003	1,201,454	1,802,181	4	1,875,270	2,344,088	4
2004	1,425,000	2,137,500	4	1,395,800	1,744,750	4
2005	1,417,375	2,126,063	4	904,825	1,176,273	4
2006	1,053,275	1,579,913	4	0	0	
2007	1,329,445	1,994,168	4	0	0	
2008	1,286,825	1,930,238	4	0	0	
2009	994,400	1,491,600	4	0	0	
2010	1,046,200	1,569,300	4	0	0	
2011	1,425,200	2,137,800	4	0	0	
2012	1,118,075	1,677,113	4	0	0	
2013	994,400	1,491,600	4	0	0	
2014	1,258,000	1,887,000	4	0	0	
2015	1,213,400	1,820,100	4	0	0	
2016	1,046,200	1,569,300	4	0	0	
2017	1,269,400	1,904,100	4	0	0	
2018	1,046,200	1,569,300	4	0	0	
2019	1,213,400	1,820,100	4	0	0	
2020	1,258,000	1,887,000	4	0	0	

4.0 LONG TERM CAPACITY ANALYSIS

The long-term disposal capacity of the Eagle Island CDF is controlled by the volume that will be occupied by the dredged material placed in the CDF and the available volume within the dikes of the CDF. Determining the volume to be occupied by the dredged material placed in the CDF is a complex issue given that the fine-grained material typical of what is placed in the Eagle Island CDF can undergo a high degree of consolidation over time resulting in significant reduction in volume. The USACE has developed a numerical model, Primary Consolidation, Secondary Compression, and Desiccation of Dredged Fill (PSDDF), for the purpose of evaluating the consolidation of dredged materials. The model is fully described in the PSDDF user's manual that comes with the software described in the reference section at the end of this report. The PSDDF model was used to evaluate the consolidation of the dredged material at Eagle Island over the next twenty years. The application of this model and the results are discussed below.

The available volume within the CDF is also a function of the surface area within the CDF and the heights of the dikes surrounding the CDF. For this evaluation it was assumed that the surface area of the CDF would not be increased from the existing footprint and that the only expansion of the CDF would be vertical. The increases in volume associated with proposed future dike raises have been evaluated and are also discussed in this section. Based on the anticipated dredge schedules and estimated consolidation of the material, a schedule of future dike raises has been prepared and is also presented.

4.1 DREDGED MATERIAL CONSOLIDATION

To accurately assess the long-term capacity of Eagle Island, the consolidation of the dredged material once it has been placed within the CDF must be evaluated. The consolidation of the dredged material begins immediately after the material has undergone sedimentation. The three primary processes that control the long-term consolidation of confined dredged material are primary consolidation, secondary compression, and desiccation. Depending on the type of dredged material, the volume occupied in the CDF by material after it has undergone consolidation can range from less than 50 to over 120 percent of the original *in situ* volume of the material. Consequently, the rate and amount of consolidation can significantly affect the long-term storage capacity of a CDF. To assist in estimating the effect of consolidation, a numerical model (PSDDF) was used to simulate the consolidation process. Details on the consolidation of the dredged material and the implementation of PSDDF for the Eagle Island CDF are presented below.

4.2 MODELING LARGE STRAIN CONSOLIDATION - PSDDF

Modeling the large strain consolidation of fine-grained materials is most effectively accomplished using computer simulation of the process such as PSDDF. PSDDF was developed in the mid 1990's and is an enhancement of PCDDF89 which itself had many predecessors. PSDDF simulates the primary consolidation, secondary compression, and desiccation processes in fine-grained soils (e.g. dredged fill) using the one-dimensional finite strain theory of consolidation, a secondary compression theory, and an empirical desiccation model. PSDDF calculates the total settlement of a dredged fill layer based on the consolidation characteristics of the soils above and/or below the layer, the consolidation characteristics of the dredged fill, local climatological data, and surface water management techniques within the containment area. This settlement is then accumulated for each compressible layer within the area, and a cumulative settlement for all dredged fill and compressible foundation layers is calculated.

4.2.1 General

Closed form analytical solution of the equations governing the primary consolidation, secondary compression, and desiccation processes in dredged materials are not available because of the highly non-linear nature of the material properties. However, incremental solutions over relatively short time periods when these coefficients can be assumed practically constant are feasible by computer techniques. In PSDDF the primary consolidation, secondary compression, and desiccation processes are solved separately to a certain point in time when the solutions are combined to determine the net impact on the dredged material. This reconciliation occurs monthly in the program to conform to the availability of reasonably accurate average evaporation and rainfall data.

4.2.2 The Primary Consolidation Processes

The mathematical model of one-dimensional primary consolidation used in PSDDF is based on the finite strain theory of consolidation. The governing equation of the consolidation process is as follows:

$$\left(\frac{g_s}{g_w}-1\right)\frac{d}{de}\left[\frac{k(e)}{(1+e)}\right]\frac{\partial e}{\partial z}+\frac{\partial}{\partial z}\left[\frac{k(e)}{g_w(1+e)}\,\frac{ds}{de}\,\frac{\partial e}{\partial z}\right]+\frac{\partial e}{\partial t}=0$$

Where:

g_s = unit weight of solids
g_w = unit weight of water
e = void ratio
$k(e)$ = coefficient of soil permeability as a function of void ratio
z = vertical material coordinate measured against gravity
s = effective stress
t = time

This equation is well suited for the prediction of consolidation in thick deposits of-very soft, fine-grained soils, such as dredged material, because it provides for the effects of:

- self-weight consolidation,
- permeability varying with void ratio,
- a non-linear void ratio-effective stress relationship, and
- large strains.

Since a closed form solution is not possible, an explicit finite difference scheme is used in PSDDF to reduce the equation to a tractable form. Once the initial and boundary conditions are defined and appropriate relationships between void ratio and effective stress and void ratio and permeability are specified, the void ratio in the consolidating layer can be calculated by the explicit finite difference technique for any future time. The void ratio distribution in the saturated dredged fill layer is used to calculate the corresponding stresses and pore-water pressures. The consolidation calculation is carried forward from the time of material deposition until the time desiccation starts. At the time desiccation starts, the void ratio for the normally consolidating dredged fill is evaluated. Normal consolidation then proceeds until one month after the desiccation start time when again the void ratio is evaluated. The process is repeated on a monthly basis until a new material is placed and desiccation starts anew or until the entire dredged layer is dried and consolidation ceases.

At each monthly interval during times when the desiccation process is active, the material thickness of the consolidating dredged material will decrease by an amount dependent on the amount of effective evaporation. The top boundary condition of the remaining consolidating material is also modified according to the amount of effective evaporation. The void ratio of the top nodal point in the consolidating layer will have a value greater than or equal to its ultimate void ratio as determined by the effective stress induced by desiccated material above. The desiccated layer then acts as a surcharge on the consolidating layer and is assumed to be free draining.

4.2.3 Input Parameters for Running PSDDF

Initial Void Ratio Correlation:

The initial void ratio is the void ratio at which sedimentation ceases and self-weight consolidation commences. As a result, the initial void ratio corresponds to the void ratio at zero effective stress in the dredged material. An initial void ratio value is required for each layer of dredge fill material and is the starting point for the self-weight consolidation calculations in PSDDF. If the void ratio-effective stress and void ratio-permeability relationships for a particular site are going to be used, the initial void ratio associated with that particular dredged material should be used. The initial void ratio of the material immediately after sedimentation can be estimated from the column settling test results as presented in the supporting data.

Specific Gravity of Soil Solids

The values of specific gravity of solids collected from representative dredged material sites have range from 2.40 to 2.75. Most natural soils exhibit a specific gravity between 2.6 and 2.8. If a dredge material is predominantly sand, a specific gravity of 2.60 to 2.70 is suitable. If the dredge material is primarily a cohesive soil, a specific gravity of 2.65 to 2.80 should be used. If the dredged material contains a high percentage of organic material, a value less than 2.60 is probably applicable for use.

Empirical Desiccation Model Parameters

Research has indicated that evaporative drying is the most cost-effective means of dewatering dredged material. Climatic conditions at the containment area significantly impact drying and thus control the effectiveness of evaporative drying and the consolidation and permeability characteristics of the dredged material.

Drying occurs in stages. First-stage drying ends and second-stage drying begins when the void ratio decreases to the void ratio corresponding to the saturation limit. During the first stage, the free water table remains at or near the surface of the dredged material though widely spaced and shallow surface cracks will likely develop. Since any non-saturated surface film will be negligible, the dredged fill remains saturated and buoyant when the void ratio is at or above the saturation limit; therefore, the term "saturation limit." During first-stage drying, the dredged fill surface settles because of the effects of primary consolidation, secondary compression, and desiccation.

As the dredged material begins to lose saturation, the free water table drops below the surface and the material develops negative pore-water pressures. The negative pore-water pressures shrink the material to a hard crust having a lower permeability and reduced evaporative rates. The evaporative rate in second-stage drying depends not only on the water conductivity of the unsaturated crust but also the crust thickness. When desiccation progresses to the limiting depth, evaporation from the dredged material effectively ceases. At this point the void ratio is at the desiccation limit and the thickness of the dried crust is equal to the depth of second stage drying.

Because of the complex nature of desiccation, an empirical model is used to estimate the settlement caused by desiccation. The three most important parameters required by the desiccation model in PSDDF are the void ratio at the saturation and desiccation limits, and the depth to which second stage drying occurs.

The values of desiccation limit, saturation limit, and depth to second stage drying have been investigated for a number of dredged material placement areas and are included in the PSDDF database. If the void ratio relationships for a particular site are utilized, it is recommended that the desiccation parameters for that site also be used.

Evaporation and Precipitation Data

Rainfall and pan evaporation data are important parameters in estimating settlement caused by desiccation. Consequently, PSDDF requires input of the monthly Class A pan evaporation potential and the average monthly rainfall. A data file in PSDDF contains the evaporation and rainfall data for site around the country to facilitate use of the program.

Evaporation Efficiency Factors

As previously noted, studies indicate that evaporation of water from dredged material occurs in two stages. During the first stage, sufficient free water is available at the surface of the material and evaporation takes place at its full Class A pan evaporation rate. Therefore, the dredged fill evaporation efficiency (CE) is equal to 1.0.

In the second stage of evaporation, drying proceeds at a fraction of the potential rate and thus CE is less than 1.0. The efficiency decreases as the depth of the dried crust increases. Observed values of CE range from 0.5 to 1.0. A value of 0.75 is recommended unless sufficient data is available to estimate CE.

Drainage Efficiency Factors

The drainage efficiency factor of the containment area is the ratio of the overland runoff volume to the rainfall volume. A drainage efficiency factor (DREFF) equal to 1.0 means that all monthly rainfall is quickly removed from the surface of the disposal area. A DREFF equal to 0.0 means that no surface drainage is provided to remove the monthly rainfall. As a result, the precipitation must be evaporated before desiccation can begin in the dredged material.

In a well-managed dredged material disposal facility, DREFF can be assumed to range from 0.8 to 1.0. The outflow weir boards are managed after sedimentation is complete and perimeter and internal trenches are excavated to promote drainage in the dredge fill. DREFF should be reduced to 0.2 to 0.3 if the placement facility is not managed.

The calculations performed by PSDDF may appear insensitive to the drainage and evaporation efficiency factors in certain instances. This is caused by the interconnection between these efficiency factors and the maximum depth of dredged material crust. If the crust thickness is small, the analysis is insensitive to the efficiency factors. In addition, the differences in intermediate settlements are usually less than ten percent. If the crust thickness is large, the calculated settlements are influenced by the values selected for the efficiency factors.

The formation of crust results in settlement caused by desiccation and the additional consolidation induced by the increased unit weight of the crust. Under normal drying conditions, the maximum crust thickness will have sufficient time to develop for the range of evaporation and drainage efficiency factors previously described. Therefore, emphasis should be placed on evaluating the depth to second-stage drying. Management action can significantly increase the second-stage drying depth, and drying depths of more than 1 ft are readily achievable in cohesive materials.

4.3 ANALYSIS OF LONG TERM CAPACITY OF EAGLE ISLAND

4.3.1 Planned Dredging Operations

To perform the Eagle Island dredged materials consolidation study it was necessary to establish a schedule of the proposed dredge events for the upper portion of Wilmington Harbor. Using the information presented Section 2, the proposed schedule for the new work dredging, and the schedule for ongoing construction activities at Eagle Island, a schedule for the placement of the dredged material in the three cells at Eagle Island was developed and is provided in Table 6. For ease of reference, this schedule will be referred to hereafter as the "Plan". The plan was developed in consideration of the following:

- The anticipated maintenance and new work dredge volumes for the next 20 years.
- The placement of dredged material in the three cells at Eagle Island should occur on a rotational basis to allow sufficient time for the solids in the slurry to consolidate before addition of the next lift.
- The new work dredging will begin in the southern portion of the upper section of Wilmington Harbor and will proceed upriver. The cell rotation should be such to limit the pumping distance of the new work material where possible.

Table 6 includes the feet of bulked dredged material to be placed in each of the cells during a particular year. These values were estimated by dividing the bulked volume from Table 5 by the square yardage of the disposal basin, and then multiplying be 3 to convert to feet. For the years prior to 2005, the yardage estimates were based on acreage of the disposal basins of 225, 260, and 260 for Cells 1, 2, and 3, respectively. For the years after 2005, it was assumed that the acreage of the disposal basins will decrease approximately 10 acres as the dikes are raised and stepped inward.

4.3.2 Consolidation Model

<u>General</u>

A consolidation model was developed for each of the three existing cells at Eagle Island using the dredging schedule shown in the Plan. A separate PSDDF simulation was conducted for of Cells 1,2, and 3, and the results were tabulated. The output files for each simulation are included with this report in the supporting data. The remainder of this section discusses the input that was used to develop the models.

Table 6 - Feet of Dredged Material Per Year

	CELL 1		CELL 2		CELL 3	
Year	**Maintenance**	**New Work**	**Maintenance**	**New Work**	**Maintenance**	**New Work**
2000			3.4			
2001					3.2	
2002		6.3	3.4			
2003				5.6	4.3	
2004	6.3					4.2
2005			5.3			2.7
2006	4.7					
2007			4.9			
2008					4.8	
2009	4.4					
2010			3.9			
2011					5.3	
2012	5.0					
2013			3.7			
2014					4.7	
2015	5.4					
2016			3.9			
2017					4.7	
2018	4.6					
2019			4.5			
2020					4.7	

Set-Up of the Model

Figures 5, 6 and 7 show the cross sections that were used for the simulations. The foundation layers and the foundation material properties were selected by considering the data developed during the field investigation and the soil models available in the PSDDF database. The dredged material placement schedule was taken from the Plan. The thickness of each slurry lift was calculated by considering the *in situ* volume of sediment to be dredged and using an appropriate bulking factor (as discussed above). The material properties for the layers of dredged materials were selected by considering the laboratory tests performed on sediment samples and matching them with similar soil types in the database. This is the preferred procedure in this stage of the analysis since the database relationships have all been tested and found compatible. In the initial stages of PSDDF simulations, adequate and accurate laboratory data is rarely available. The preferred procedure is to use data developed locally to identify a soil in the database similar in properties and use it. As the analysis matures and more data becomes available, a site-specific database can be developed.

Two types of dredged material were considered for the simulation. One type was comprised of the sediments to be removed by maintenance dredging. The other was material to be removed as part of the harbor deepening project consisting of previously undisturbed material. This material is referred to as "new work" material. These materials are described as follows:

- Maintenance material is a fine-grained clay/silt that behaves very much as the material currently in the CDF.
- New work material contains both sand and rock excavated from the channel bottom, as well as fine-grained sediments, and differs considerably from maintenance material.

In consideration of the above, the soil model chosen for the maintenance material is a marine silt while the new work material is a sand. In addition, the following key assumptions were made regarding physical parameters for the analysis:

- an initial void ratio of 10.4 was selected for the clay/silt based on the outcome of the column sedimentation tests;
- values for desiccation were selected to match the soil models.
- rainfall data and the evaporation data listed for Charleston, S. C. were selected to represent Wilmington, N. C.
- to set the surface water efficiency factor, it was assumed that the CDF will be well managed, the drainage ditches will be cut and maintained, vegetation will be controlled, and any surface water will be decanted as soon as possible.

With the above assumptions, the values recommended in the database were input.

Model Predictions

The output from simulation of Cells 1, 2, and 3 is plotted in Figures 8, 9, and 10 respectively. These figures show the elevation of the dried material in each of the cells over time.

Limitations

Since the simulation is a computer model of a real process, it will always be an approximation. In addition, the model as currently constituted still contains a lot of assumed data. As time progresses and predictions can be checked against actual field measurements, the model can be improved and made more reliable.

4.4 SUMMARY OF LONG TERM CAPACITY REQUIREMENTS

The results of the PSDDF modeling were combined with the ponding requirements of 4 feet established in Section 3 and the recommended freeboard of 2 feet to estimate the total dike elevation required on a yearly basis. Plots of this information are included in Figures 8, 9, and 10.

5.0 DIKE RAISES

The long term capacity requirements established in the previous section were used to develop a dike-raising plan for Eagle Island. Various dike-raising scenarios were considered and evaluated. The proposed dike-raising plan is discussed below.

5.1 DATA COMPILATION

As part of the dike raising effort of this project, accurate topographic data for the site were required. Therefore, electronic copies of all the existing survey data and construction staking for Eagle Island were gathered and combined into one base survey. Most of this data was contained in aerial surveys and construction documents provided by the Wilmington District. In some areas where recent construction work had altered ground elevations, a contractor provided additional survey data. The various surveys were combined, and the most recent data were used to generate a digital terrain model of the site. The terrain model was used in conjunction with the proposed dike cross sections to determine placement of the dike centerlines, calculate the amount of cut/fill volume necessary to construct higher dikes and to calculate the volume available within the cells following dike-raising activities.

5.2 FUTURE DIKE DEVELOPMENT

Future dike raises for the Eagle Island CDF were developed based on the following:

- capacity requirements established in Sections 3 and 4;
- the availability of material for dike construction; and,
- the desire to incrementally load the foundation soils to the greatest extent possible to facilitate consolidation.

The schedule is a modification of the dike raising schedule developed by the Wilmington District (Snipes, unpublished). Various cross-sections for the dikes were considered which sought to minimize construction volumes, limit the need for geotextiles, and maximize the interior acreage available for disposal. The dike cross-sections are discussed in more detail in Section 6. The cross-sections selected for future dike raises are similar to those proposed by the Wilmington District, with some minor modifications.

The process of raising the dikes, which began in 1997, will continue over the next eighteen years (ending in 2018) and will be split into four independent stages for each cell. During this period, the existing dikes surrounding Cells 1, 2 and 3 are to be incrementally raised from approximately +26 feet msl to +38 feet msl. Each cell will be raised on a rotating basis leaving at least one cell available to receive dredged material at any given time. The dike-raising schedule is as follows:

Table 7 - Proposed Dike Raising Schedule

Year	CELL 1		CELL 2		CELL 3	
	Stage	Elevation	Stage	Elevation	Stage	Elevation
2000		27.5		25.5		25.5
2001	I	30			I	30
2002			I	30		
2003						
2004	II	34				
2005			II	34		
2006						
2007						
2008					II	34
2009						
2010			III	36		
2011						
2012	III	36				
2013						
2014					III	36
2015	IV	38				
2016			IV	38		
2017					IV	38
2018						
2019						
2020						

Dike raising activity has already occurred at the site with Cell 1 constructed to 27.5 feet msl and Cells 2 and 3 to 25.5 feet msl. During the next round of raises, the dikes for each cell will be raised an average of four (4) feet to an elevation of 30 feet msl. The process will begin by simultaneously raising Cells 1 and 3 in the spring of 2001 and will finish by raising Cell 2 in the spring of 2002. This round of raises is designed to take the dikes as high possible without increasing the existing base width of the dikes and use as little fill material as possible. The intent is to create as much capacity as possible to accommodate the large volumes of new dredge material that will be placed in the CDF over the next three to five years. The fill material for this stage of the raising process shall be taken mostly from Cell 3 and with some material coming from Cell 1, particularly the sand deposits at the northern and southern ends of Cell 1.

The next round of the dike raising will begin in the spring of 2004 immediately following the current round. The dikes will be raised four (4) feet to an elevation of 34 feet msl during the years 2004 to 2008, and the base of the structures will be widened to create a larger surface for future dike raisings. Cell 1 will be raised first, followed by Cell 2 in 2005 and then by Cell 3 in 2006. While these dike raises will require substantial amount of material for construction, it is anticipated that the new work material placed in each of the cells prior to the dike raise will dry quickly and be available to raise the dikes.

The next stage of dike raising will begin in 2010 on Cell 1 and continue through 2014, finishing on Cell 3. The dikes will be raised two (2) feet to an elevation of 36 feet msl. The fill dirt for this stage shall be taken directly from the dried dredged material on the interior of the respective cell being modified. Also, the raising shall be scaled from the inboard crest of the previously widened dike to accommodate a small (20 feet wide) travel path on the outboard side of the dike.

The final stages will follow the same procedure as in the previous stage, rising the dikes 2 feet and scaling from the inboard crest of the existing dikes. The final stage will begin in 2015 on Cell 1, followed by Cell 2 in 2016 and Cell 3 in 2017. The final stage will raise the dikes to elevation 38 msl. The cross sections illustrating the above evolution for Cells 1, 2, and 3 are shown in Figures 11, 12, and 13.

Using the information above, the dike raises were modeled and analyzed to determine both the volume necessary to build the dikes in each stage and the volume of increased storage attained from each raise. Details of the analysis are provided in the supporting data. As part of the analysis it was necessary to assume a base elevation of the material within the cells. Therefore, the available topographic data was used to determine the average base elevation of the material in each of the cells in the spring of 2000. The base elevation for each of the cells is as follows:

- Cell 1 14.3 feet
- Cell 2 17.6 feet
- Cell 3 16.5 feet

Using this information, the amount of capacity created in the cell for each dike raise and the volume of fill necessary to construct the dike raises were estimated and are summarized below in Table 8.

Table 8 - Summary of Planned Construction and Storage Volumes

CELL 1				CELL 2				CELL 3			
Year	**Dike Hgt. (Feet)**	**Dike Constr. Volume (CY)**	**Storage Volume (CY)**	**Year**	**Dike Hgt. (Feet)**	**Dike Constr. Volume (CY)**	**Storage Volume (CY)**	**Year**	**Dike Hgt. (Feet)**	**Dike Constr. Volume (CY)**	**Storage Volume (CY)**
2001	30	88,910	4,928,765	2002	30	82,100	4,400,758	2001	30	132,202	4,864,485
2004	34	458,451	6,291,390	2008	34	205,628	6,012,861	2009	34	319,358	6,478,562
2015	38	79,534	7,680,273	2017	38	45,311	7,648,735	2018	38	74,387	8,116,359

Note: For Table 8, the volumes associated with raising the dikes to elevation 36 feet msl and 38 feet msl are combined. The table incorporates a 2 feet allowance for freeboard. Thus the volumes calculated for 30, 34 and 38 feet provide for a wet fill useable volume calculated to elevations 28, 32 and 36 feet respectively.

Each year that a dike is raised, additional volume is generated within the respective cell because of the soil removed to construct the dike. This figure was not included in Table 8. The resulting capacity for the entire Eagle Island CDF is about 23,445,000 cubic yards. Please note that the volumes calculated by the efforts previously described represent actual cubic yard volumes without considering sediment-bulking factors. It is important to recognize the differences in use of the term “volume” in this sense of creating volume in the CDF with use of the term “volume” when discussing *in situ* sediments. The volume of the unconsolidated sediments in the harbor changes considerably when the material is dried and consolidated in the CDF.

5.3 SUMMARY COMPARISON OF DIKE RAISES AND YEARLY CAPACITY REQUIREMENTS

A comparison of the long-term capacity requirements (i.e. – required dike heights) and the proposed dike raises for Cells 1, 2, and 3 are shown in Figures 8, 9, and 10, respectively. As shown in these Figures, there are times when required dike elevations will exceed the existing dike heights by a small amount. This occurrence will be manageable in the field since the required dike elevation includes 4 feet for ponding and 2 feet for freeboard. Furthermore, mudline elevations shown in the figures does not include losses from removal of material to construct dikes which will reduce the actual mudline by over 1.5 feet in each of the cells over the 20 year period

6.0 DIKE STABILITY ANALYSIS

6.1 GENERAL

The dike elevations identified in the dike-raising schedule were developed to provide the required storage capacity. However, the nature of the foundation soils below the perimeter dikes of the CDF and the strength of the soils used to construct the dikes may limit the Wilmington District's ability to raise the dikes as required. Therefore, geotechnical studies were performed for the purpose of evaluating the potential to raise the existing perimeter dikes at the Eagle Island CDF. A detailed report of these evaluations is presented in Volume II "*Embankment Stability Analyses*" of this report. A summary of the findings is included in this section.

Perimeter dike side slope stability was evaluated using limit equilibrium methods and input from laboratory and field test data as well as historical data related to the performance of the existing dikes. An example of dike performance is shown in Photograph 5 where existing, stable steeply sloped embankments exist adjacent to a spillway pipe support structure during construction.

Photograph 5. Existing Steep Cut Slopes

6.2 SIDE SLOPE STABILITY

The design of the future dike raises at Eagle Island were developed based on the Wilmington District's experience at the site, the need to meet certain operational constraints, and the nature of the material used for dike construction. Numerous iterations of various dike configurations were considered prior to selection of the recommended design. The recommended design for each of the cells is presented in Figures 11, 12, and 13. The design consists of a 4:1 (horizontal:vertical) slope on the exterior slopes and a 3:1 slope on the interior section of the dikes. The embankment height at elevation 38 feet msl will be reached in four stages, first raising embankments from their existing level to 30 feet msl; and then, followed each time by monitoring, incrementally raising the dikes to 34, 36 and 38 feet msl. The dike raise to 34 feet msl will also involve widening the base of the dike and steeping the structure inward.

The dike stability calculations were done for the raises to 30, 34, and 38 feet msl. A separate analysis for the raise to 36 feet msl was not considered necessary since the raise to 38 feet essentially included the raise raise to 39 feet.

The results of the dike stability analysis are presented in Table 9 on the following page. As shown in the table, the analysis indicates that under almost all circumstances the proposed cross-sections will have an acceptable minimum factor above Dames & Moore's recommended minimum factor of safety for CDF dikes of 1.3. For those few instances when the factor of safety drops below 1.3 (38 feet raise at Sections 11 and 19), construction can be accomplished either by carefully observing performance in the field or by moving the edge of the dike inboard by 5-10 feet.

The recommended design is made on the explicit condition that regular monitoring of instrumentation demonstrates that the highly plastic organic clay/silt (classified as "OH" or "MH" by the Unified Soils Classification System) foundation soils remain stable during embankment construction. Stability analyses utilizing conservative soil strength parameters indicates that this construction can be accomplished with a minimum short term factor of safety of about 1.3 against slope failure. After completion of the vertical dike expansion and regular monitoring ceases, the factor of safety should exceed 1.5.

As long as these minimum factors of safety are maintained, it is not expected that excessive strains or local yielding within the upper clay will occur. This recommendation is subject to modification during actual raising of the perimeter dikes, dependent upon the observed behavior of the perimeter dikes and foundation soils. Should soil strength, soil drainage and pore pressure conditions be better than assumed in the stability analyses, steeper recommended side slopes could be built and the time between vertical expansion efforts shortened. Weaker soils, poorer drainage and too fast a rate of dike construction would require flatter side slopes or other modifications to the dike design or CDF operating procedures.

Table 9 - Summary of Stability Analyses

Section	Embankment Elevation (feet, MSL)	Minimum Short Term Factor of Safety	
		Outboard Failure	Inboard Failure
Section 1	30	1.91	2.70
	32	1.72	2.63
	38	1.58	2.31
Section 6	30	1.47	2.31
	32	1.50	2.17
	38	1.41	1.87
Section 11	30	1.40	2.61
	32	1.31	2.44
	38	1.29	1.89
Section 18	30	1.72	2.56
	32	2.54	2.55
	38	1.42	2.07
Section 19	30	1.33	2.62
	32	1.34	2.34
	38	1.24	2.03
Section 23	30	1.45	2.67
	32	1.51	3.03
	38	1.63	2.65
Section 28	30	2.68	2.35
	32	2.35	2.19
	38	1.85	1.94
Section 31	30	1.86	3.71
	32	1.87	3.09
	38	1.48	2.55
Section 35	30	2.22	2.66
	32	2.06	2.34
	38	1.47	2.16

6.3 INSTRUMENTATION AND MONITORING REQUIREMENTS

A slope-monitoring program is required to assure that the minimum necessary operating factors of safety can be maintained throughout the operating life of the dike. Such monitoring should consist of survey monuments, settlement points, and inclinometers spaced generally at 1,000-foot intervals around the dike perimeter. Survey cross-section data should also be obtained at regular intervals to verify the side slope profile actually constructed. An experienced geotechnical engineer who is familiar with the site conditions and design methodology for the project should regularly review all of this data. The recommended minimum frequency of monitoring is approximately monthly, but this frequency may be subject to change if dike construction methods or instrumentation data indicate that more frequent monitoring is necessary in a localized area or for a specific time duration.

6.4 FOUNDATION SETTLEMENT

Analyses of consolidation settlement estimate the range of settlement under the projected dike crest elevation of 32 feet msl from two to four (2 to 4) feet. This estimate varies largely due to the varying thickness of compressible soils present beneath the site.

Soil deformation and settlement is anticipated to be reasonably uniform beneath the dike crest, but will likely reflect local variations in thickness of the compressible foundation soils along the centerline. Soil deformations beyond the embankment toe along the exterior of the dike is anticipated to be minimal (less than one to three inches).

6.5 CONCLUSIONS OF STABILITY ANALYSIS

The stability analysis confirms that the proposed dike raises will be stable within a safety factor of approximately 1.3.

7.0 SITE MANAGEMENT AND OPERATIONS

7.1 GENERAL

The analysis performed in the previous sections indicates that the Eagle Island CDF can meet the three following objectives inherent in design and operation of the Eagle Island CDF:

- to provide for adequate storage capacity for meeting dredging requirements;
- to maximize efficiency in retaining the solids, limiting effluent releases to within regulatory limits; and
- to maximize settling and consolidation efficiency by promoting efficient drainage and drying.

However, proper management of the site will be critical to ensure that the objectives are achieved. Site management and operation guidelines for the Eagle Island CDF are described in this section

7.2 SCHEDULE

A detailed schedule for the Eagle Island CDF has been developed and is provided in Table 10, presented on the following pages. This schedule includes the anticipated dredge volumes, placement of the dredged material, bulking and consolidation of the dredged material, dike raises, and volumes of earth required for the raises. The schedule is a summary of the information presented in the previous sections of this report.

Table 10 – Schedule of Anticipated Dredging Consolidation and Dike Raising

	2000				2001				2002				2003				2004				2005				2006				2007			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
CELL 1																																
Activity					Dike Raise		Idle				New Work Dredge				Idle		Dike Raise		Maintenance Dredge				Idle		Drying		Maintenance Dredge				Idle	
Comments											Lwr Bruns - 4th E Jetty																					
Dike Height (ft)	27 ft				30 ft												34 ft															
Borrow Volume (x1,000 cy)					89								0				458												0			
Borrow Source					Cell 1and 3																											
Loss in Mudline		0				-0.2				0				0				-1.3				0				0				0		
New Work (x1,000 cy)											1,875																					
Maintenance (x1,000 cy)																			1,425								105					
Feet of mud in					0				0				6.3				0				6.3				0				4.7			
Consolidation (ft)							-4.2				-0.1				0				-0.7				0				-4.4				0	
Mud Elevation (ft)	20.2	20.2	20.2	20.2	20.2	20.2	15.8	15.8	15.5	15.5	15.7	15.7	22.0	22.0	22.0	22.0	22.0	20.7	20.0	20.0	26.3	26.3	26.3	26.3	26.3	26.3	21.9	21.9	26.6	26.6	26.6	26.6
Required Dike Height (ft)													28.0					*			32.3								32.6			
CELL 2																																
Activity	Dike Raise		Maintenance Dredge						Dike Raise		Maintenance Dredge				New Work Dredge				Idle		Dike Raise		Maintenance Dredge				Idle		Drying		Maintenance Dredge	
Comments															4th E Jetty - Anch Basin																	
Dike Height (ft)	25.5 ft								30 ft												34 ft											
Borrow Volume (x1,000 cy)									82												206											
Borrow Source (x1,000 cy)	Cell 2								Cell 2												Cell 2											
Loss in Mudline		0.0				0.0				-0.2				0.0				0.0				-0.6				0.0				0.0		
New Work (x1,000 cy)															1,875																	
Maintenance (x1,000 cy)			951								951												1,417								1,329	
Feet of Mud in (ft)	0				3.4				0				3.4				5.6				0				5.3				0			
Consolidation (ft)							0				-2.6				-2.3				0				-0.8				0				-3.8	
Mud Elevation (ft)		17.6	17.6	17.6	21.0	21	21	21	21.0	20.8	18.2	18.2	21.6	21.6	19.3	19.3	24.9	24.9	24.9	24.9	24.9	24.3	23.5	23.5	28.8	28.8	28.8	28.8	28.8	28.8	25	25
Required Dike Height (ft)					27.0								27.6				30.9	*							34.8	*						
CELL 3																																
Activity	Dike R.		Idle		Dike Raise		Maintenance Dredge				Idle				Maintenance Dredge				New Work Dredge				New Work Dredge				Idle		Drying		Idle	
Comments															New Work & Maint. Mixed				CFR -HH RR Bridge				HH RR Bridge - End									
Dike Height (ft)	25.5	ft			30 ft																											
Borrow Volume (x1,000 cy)					132																				0							
Borrow Source	Cell 3				Cell 3																											
Loss in Mudline (ft)		0				-0.4				0				0				0				0				0				0		
New Work (x1,000 cy)																			1,396				905									
Maintenance (x1,000 cy)							904								1,201																	
Feet of Mud in (ft)	0				0				3.2				0				4.3				4.2				2.7				0			
Consolidation (ft)			0				0				0				-2.4				-2.8				-0.9		0		0				-0.2	
Mud Elevation (ft)		16.5	16.5	16.5	16.5	16.1	16.1	16.1	19.3	19.3	19.3	19.3	19.3	19.3	16.9	16.9	21.2	21.2	18.4	18.4	22.6	22.6	21.7	21.7	24.4	24.4	24.4	24.4	24.4	24.4	24.2	24.2
Required Dike Height (ft)									25.3								27.2				28.6				30.4	*						

Notes: * Estimated required dike heights exceeds existing dike height. Prior to dredging, site conditions should be assesses and an additional small 2-foot berm placed on the top of the dike if it warranted.

indicates dike raise | indicates new work dredging | indicates maintenance dredging

Table 10 – Schedule of Anticipated Dredging Consolidation and Dike Raising (continued)

	2008				2009				2010				2011			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
CELL 1																
Activity	Drying		Idle		Drying		Maintenance Dredge				Idle		Drying		Idle	
Comments																
Dike Height (ft)																
Borrow Volume (x1,000 cy)																
Borrow Source																
Loss in Mudline (ft)		0				0				0				0		
New Work (x1,000 cy)																
Maintenance (x1,000 cy)								994								
Feet of mud in (ft)	0				0				4.4				0			
Consolidation (ft)			-3.4				-0.2				0				-3.1	
Mud Elevation (ft)	26.6	26.6	23.2	23.2	23.2	23.2	23.0	23.0	27.4	27.4	27.4	27.4	27.4	27.4	24.3	24.3
Required Dike Height (ft)									33.4							
CELL 2																
Activity			Idle		Drying		Idle		Dike Raise		Maintenance Dredge				Idle	
Comments																
Dike Height (ft)		ft							36 ft							
Borrow Volume (x1,000 cy)	0								26							
Borrow Source																
Loss in Mudline (ft)		0.0				0.0				-0.1				0		
New Work (x1,000 cy)																
Maintenance (x1,000 cy)												1,046				
Feet of Mud in (ft)	4.9				0				0				3.9			
Consolidation (ft)			0				-3.4				-0.2				0	
Mud Elevation (ft)	29.9	29.9	29.9	29.9	29.9	29.9	26.5	26.5	26.5	26.4	26.2	26.2	30.1	30.1	30.1	30.1
Required Dike Height (ft)	35.9	*											36.1	*		
CELL 3																
Activity	Dike Raise		Maintenance Dredge				Idle		Drying		Idle		Drying		Maintenance Dredge	
Comments																
Dike Height (ft)	34	ft														
Borrow Volume (x1,000 cy)	319															
Borrow Source																
Loss in Mudline (ft)		-0.9				0				0				0		
New Work (x1,000 cy)																
Maintenance (x1,000 cy)				1,287												1,425
Feet of Mud in (ft)	0				4.8				0				0			
Consolidation (ft)			-0.1				0				-3.2				-0.1	
Mud Elevation (ft)	24.2	23.3	23.2	23.2	28.0	28	28	28	28.0	28	24.8	24.8	24.8	24.8	24.7	24.7
Required Dike Height (ft)					34											

	2012				2013				2014				2015			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
CELL 1																
Activity	Dike Raise		Maintenance Dredge				Idle		Drying		Idle		Dike Raise		Maintenance Dredge	
Comments																
Dike Height (ft)	36	ft											38	ft		
Borrow Volume (x1,000 cy)	46												34			
Borrow Source																
Loss in Mudline (ft)		-0.1				0				0				-0.1		
New Work (x1,000 cy)																
Maintenance (x1,000 cy)				1,118											1,213	
Feet of mud in (ft)	0				5				0				0			
Consolidation (ft)			-0.2				0				-3.4				-0.2	
Mud Elevation (ft)	24.3	24.2	24.0	24.0	29.0	29.0	29.0	29.0	29.0	29.0	25.6	25.6	25.6	25.5	25.3	25.3
Required Dike Height (ft)					35.0											
CELL 2																
Activity	Drying		Idle				Maintenance Dredge				Idle		Drying		Idle	
Comments																
Dike Height (ft)																
Borrow Volume (x1,000 cy)																
Borrow Source																
Loss in Mudline (ft)		0				0				0				0		
New Work (x1,000 cy)																
Maintenance (x1,000 cy)								994								
Feet of Mud in (ft)	0				0	0			3.7				0			
Consolidation (ft)			-2.6				-0.3				0				-2.6	
Mud Elevation (ft)	30.1	30.1	27.5	27.5	27.5	27.5	27.2	27.2	30.9	30.9	30.9	30.9	30.9	30.9	28.3	28.3
Required Dike Height (ft)									36.9	*						
CELL 3																
Activity			Idle				Idle		Dike Raise		Maintenance Dredge				Idle	
Comments																
Dike Height (ft)	36	ft							36	ft						
Borrow Volume (x1,000 cy)	0								44							
Borrow Source	Cell 3															
Loss in Mudline (ft)		0				0				-0.1				0		
New Work (x1,000 cy)																
Maintenance (x1,000 cy)												1,258				
Feet of Mud in (ft)	5.3				0				0				4.7			
Consolidation (ft)			0				-3.9				-0.2				0	
Mud Elevation (ft)	30	30	30	30	30	30	26.1	26.1	26.1	26	25.8	25.8	30.5	30.5	30.5	30.5
Required Dike Height (ft)	36	*											36.5	*		

Notes: * Estimated required dike heights exceeds existing dike height. Prior to dredging, site conditions should be assesses and an additional small 2-foot berm placed on the top of the dike if it warranted.

indicates dike raise | indicates new work dredging | indicates maintenance dredging

Table 10 – Schedule of Anticipated Dredging Consolidation and Dike Raising (continued)

	2016				2017				2018				2019				2020			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
CELL 1																				
Activity			Idle		Drying		Idle		Drying			Maintenance Dredge			Idle		Drying		Idle	
Comments																				
Dike Height (ft)																				
Borrow Volume (x1,000 cy)																				
Borrow Source																				
Loss in Mudline (ft)		0				0				0				0				0		
New Work (x1,000 cy)																				
Maintenance (x1,000 cy)												1,046								
Feet of mud in (ft)	5.4				0				0				4.6				0			
Consolidation (ft)			0				-3.7				-0.2				0				-3.2	
Mud Elevation (ft)	30.7	30.7	30.7	30.7	30.7	30.7	27.0	27.0	27.0	27.0	26.8	26.8	31.4	31.4	31.4	31.4	31.4	31.4	28.2	28.2
Required Dike Height (ft)	36.7												37.4							
CELL 2																				
Activity	Dike Raise			Maintenance Dredge			Idle		Drying		Idle		Drying			Maintenance Dredge			Idle	
Comments																				
Dike Height (ft)	38	ft																		
Borrow Volume (x1,000 cy)	20																			
Borrow Source																				
Loss in Mudline (ft)		-0.1				0				0				0				0		
New Work (x1,000 cy)																				
Maintenance (x1,000 cy)				1,046												1,213				
Feet of Mud in (ft)	0				3.9				0				0				4.5			0
Consolidation (ft)			-0.1				0				-2.7				-0.1				-3.1	
Mud Elevation (ft)	28.3	28.2	28.1	28.1	32	32	32	32	32	32	29.3	29.3	29.3	29.3	29.2	29.2	33.7	33.7	30.6	30.6
Required Dike Height (ft)					38												39.7	*		
CELL 3																				
Activity	Drying		Idle		Dike Raise			Maintenance Dredge			Idle		Drying		Idle		Drying		Maintenance Dredge	
Comments																				
Dike Height (ft)					38	ft														
Borrow Volume (x1,000 cy)					30															
Borrow Source																				
Loss in Mudline (ft)		0				-0.1				0				0				0		
New Work (x1,000 cy)																				
Maintenance (x1,000 cy)								1,269											1,258	
Feet of Mud in (ft)	0				0				4.7				0				0			
Consolidation (ft)			-3.3				-0.2				0				-3.3				-0.2	
Mud Elevation (ft)	30.5	30.5	27.2	27.2	27.2	27.1	26.9	26.9	31.6	31.6	31.6	31.6	31.6	31.6	28.3	28.3	28.3	28.3	28.1	28.1
Required Dike Height (ft)									37.6											

Notes: * Estimated required dike heights exceeds existing dike height. Prior to dredging, site conditions should be assesses and an additional small 2-foot berm placed on the top of the dike if it warranted.

indicates dike raise | indicates new work dredging | indicates maintenance dredging

7.3 DREDGING OPERATIONS

The manner in which the dredging operations are performed will significantly impact the operations of the CDF. The first step in the dredging process is the award of the dredging contract. Every effort should be made to award the contracts prior to the dredging window (August 1 through January 31) so that the dredge contractor can take advantage of the entire dredge window if need be. As noted previously, the capacity analysis was performed assuming that the maintenance of the upper portion of Wilmington Harbor will be performed with an 18-inch hydraulic cutterhead dredge. If a larger dredge is used, care should be taken to ensure that the discharge from the CDF meets the targeted water quality goals.

Prior to placement of dredged material into a particular cell, the interior should be graded, ditches filled, and mounds removed. In addition, if thick stands of *Phragmites* are present, they should be cut and the stalks removed. The discharge pipe from the dredge should be placed in the cell receiving the slurry as far from the weirs as possible. If short-circuiting is observed once dredging commences, it may be necessary to move the discharge point.

The discharge pipes should be monitored to ensure that there is not excessive build up of sands at the discharge point. This is typically not a problem for maintenance dredging, but it can be a significant problem for new work dredging. To facilitate future dike raises, during new work dredging it is recommended that the discharge point be moved along the interior of the dikes such that the coarse grain material is placed along the inner toe of the dike. This approach will place much of the material required for future dike raises directly where it will be needed.

To achieve maximum capacity of the CDF, the thickness of the lifts placed in a given cell should be limited to no more than 4 feet per dredge event (preferably 3 feet). The use of thin lifts will allow the dredged material to dry over the entire lift. If thicker lifts are used, the lower portions of the lift will not consolidate which will impact the long-term capacity of the site.

Scheduling of the use of the cells within the CDF will be critical to achieving the maximum storage capacity for the site. Ideally, after dredged material is placed into a cell, the cell would undergo a full two-year de-watering process before being used again. Under the normal maintenance dredging requirements, a three-year rotation of the cells should be practical. However, during periods in which the new work dredging will be occurring, it will be necessary to place dredge material into a cell two-years in a row and then allow only 1 year for drying before being used again. During this period, aggressive dewatering efforts will be required to achieve the maximum consolidation possible. The anticipated cell rotation for the Eagle Island CDF is provided in Table 10.

7.4 SURFACE WATER MANAGEMENT

Hydraulic dredging adds several volumes of water for each volume of sediment removed. After the dredged material has fallen out suspension from the dredge slurry, the excess water will be discharged as effluent from the CDF. The amount of water will be dependent primarily upon design and operation of the dredge, physical characteristics of the sediment, and operational characteristics of the CDF itself. When the dredged material is initially deposited in the CDF, the volume of water to be managed is considerable. Effective use of weirs to control discharge will be crucial.

The purpose of the weir structure is to regulate the release of ponded water from the containment area. Proper weir design and operation will abet settling and limit resuspension and withdrawal of settled solids. Operations at Eagle Island have already shown effective use of weirs in its ongoing operations.

7.4.1 Placement of Weirs and Inflow Points

The weirs for the Eagle Island CDF were recently replaced and are in excellent shape. Experience from the 1999 and 2000 dredge seasons indicate that the weirs are functioning well and have sufficient weir length for the maintenance dredge activities. The weir lengths should also be sufficient for the new work dredge activities assuming the larger dredges used for new work dredging are not used continuously for extended periods of time. Under such conditions, it may be difficult to maintain water quality due to the high outflow rate required at the weirs.

The weirs are located on the western dike for each cell and discharge into the Brunswick River. The discharge pipe from the dredge should be located as far away as practicable from weirs to maximize time for sedimentation prior to discharge of the water from the CDF. Ideally, the dredged pipes should be moved periodically to avoid the buildup of coarse grain material in one area and to maintain a gentle slope from the discharge point to the area in which the weirs are located.

7.4.2 Utilization of Weirs in Surface Water Management

The management of surface water during the disposal operation can be accomplished by controlling the elevation of the outlet weirs throughout the disposal operation. At the beginning of a dredge disposal operation, the boards in the outlet weir should be set at an elevation which ensures that the ponded water will be deep enough for zone settling to occur as the cell is being filled. Slurry is then pumped into the cell and no effluent is released until the water level reaches the weir crest elevation. Once the water level in the CDF reaches the weir crest elevation, effluent is released from the cell at about the same rate as slurry is pumped into the cell.

Solids concentration in the CDF discharge should be monitored at least twice a day during dredge operations and the weir elevations increased as necessary to lengthen the retention time in the CDF until the water quality requirements are met. Based on the evaluation of the sediments from the upper portion of Wilmington Harbor, it is anticipated that ponding depths may range from 2 to 6 feet.

The ponding depth decreases as the thickness of the dredged material deposited in the cell increases. Consequently, the weir crest elevation is raised by adding stoplogs to maintain the desired ponding depth and effluent quality. After completion of the dredging operation and the activities requiring ponded water, the water is removed as quickly as effluent water quality standards will allow. Management at this stage consists of keeping the weir boarded to an elevation just above the level of the dredged material fill. As is discussed in Section 4, removal of ponded water is essential to expose the dredged material surface to evaporation and promote the formation of a dried surface crust.

Some erosion of the newly exposed dredged material may be inevitable during storm events; therefore, weirs should be boarded at a level above the dredged material surface to pond the rainwater within a small area at the weir to avoid excessive erosion of material. The potential for erosion will be minimized once the dried crust begins to form within the containment area. As the fill consolidates, the weir boards should be periodically lowered to maintain the small ponded area.

7.5 SITE DEWATERING

As is discussed in Section 4, consolidation and desiccation (evaporative drying) are processes that will affect the long-term storage capacity of the CDF. Measures to abet the dewatering of the dredged material are critical to achieving the greatest long-term capacity possible. The primary means of enhancing drying and consolidation of the dredged material is removal of surface water from the CDF. After the material is placed in the CDF and the surface water is drained, a crust will form on the deposited material as it starts to dry. Cracks will form in the crust and the crust will become thicker as the drying extends deeper into the material. Photograph 6 is typical of crust formation within the Eagle Island CDF.

Photograph 6. Perimeter Trenching and Development of a Crust of Desiccated Soil

In order for the drying to continue, any surface water that accumulates must be removed. This is accomplished through the construction of trenches throughout the CDF that drain water to the weirs where it is discharged. Typically, two types of trenches are constructed within the CDF, perimeter trenches and interior trenches. Perimeter trenches are constructed along the toe of the dike and serve as the primary means of draining the site. They should be constructed as soon after the completion of dredging as possible. Initially, the banks of the ditch will slough back in; however, over time, it should be possible to construct a ditch that does not collapse. Once the perimeter ditches are constructed, the majority of the site should be free of standing surface water. However, as the drying process continues, the depth of the cracks in the crust increases and water collects in the crevices limiting drying. Therefore, it is necessary to construct trenches throughout the interior of the cell to promote drainage of the water from the cracks. Interior trenches should be constructed to take advantage of the natural grade within the CDF to the greatest extent possible and should drain to the perimeter trench. The trench spacing should be as close together as practical and deep enough to allow drainage from the cracks in material. Once constructed, the trenches should be monitored to insure the ditches are draining and periodically deepened as conditions permit.

7.6 DIKE CONSTRUCTION

7.6.1 Dike Design

The cross-sections for future dike raises were discussed previously in Section 5. The dike raisings will take place in 4 stages. The first stage takes the dikes to an elevation 30 feet msl on the current base. Due to the concern about the availability of suitable dike construction material, it is recommended that the Stage I dike raise be accomplished by building the dike first to 28 feet and then to 30 feet under the same contract. This approach will ensure that a dike elevation of at least 28 is achieved.

Stage II widens the base of the dike for future raises and increases the top elevation to 34 feet msl. The third step raises the top elevation to 36 feet msl. Cell 1 will need to be raised to 38 feet in 2015 while Cells 2 and 3 will not need to be raised to 38 feet until 2016 and 2017, respectively. Because of concerns about availability of suitable material, Stage III and Stage III have been separated into separate raising events. If large volumes of adequate material are available, these raises may be combined at the discretion of the District Engineer. Analysis has shown that construction of Stage III and Stage IV in a single event would be stable.

The cross-sections of the proposed dike raises for Cells 1, 2, and 3 are shown in Figures 11, 12, and 13 respectively. Generally, the dimensions of the dikes are as follows:

Table 11 – Dimensions of the Proposed Dike Raises for Cells 1, 2, and 3

STAGE	I	II	III	IV
PERIMETER DIKES				
Elevation	30 feet	34 feet	36 feet	38 feet (this may be combined with Stage III)
Outboard Slopes	4:1	4:1	4:1	4:1
Inboard Slopes	3:1	3:1	3:1	3:1
Width at Top of Dike	20 feet	44 feet	34 feet	20 feet
CROSS DIKES				
Elevation	30 feet	34 feet	36 feet	38 feet (this may be combined with Stage III)
Side Slopes	3:1	3:1	3:1	3:1
Width At Top Of Dike	30 feet	66 feet	44 feet	36 feet

The design of the cross-sections assumed that the existing roadway would be maintained around the perimeter of the dike at the same location as the existing roadway.

7.6.2 Identifying and Evaluating Suitable Material

Dikes are to be constructed from dried dredged material taken from the interior of the CDFs. Typically, the primary types of material present in the CDF are fine-grained silts and clay with limited quantities of sand. However, following the new work dredging activities, it is anticipated that there will be large quantities of sand and rock in the CDF, which could be used for dike constructions. The qualities of the various material types are discussed below.

<u>*Fine-grained Material*</u>

The silts and clays that predominate the maintenance material have high plastic and liquid limits, high *in situ* water contents, and are poor construction materials. The soils will be difficult to compact, and the moisture content will be hard to control. Consequently, the soils will have to be located, excavated and placed "as found". However, once placed, the fine-grained material has a low porosity, which limits the seepage of water through the dikes. In addition, grasses that stabilize the soils and reduce erosion on the slopes grow well in the fine grain material. Furthermore, tests of the existing silts in the cells indicated maximum densities in the range of 60 to 70 pounds per cubic foot (corresponding to a void ratio of 2.4), which is low relative to other materials. Consequently, dikes constructed of this material will be lighter and, therefore, be less subject to settling on soft foundations.

Stripping soil at favorable moisture content and density will make transport and placement application easier. Samples for investigating and evaluating *in situ* soils for excavation is probably best obtained using Drive Tube samplers. The device works well in soft, shallow soils, and the results can be rapidly evaluated.

The recommended procedure for assessing the soils is to take Drive Tube samples of various places in the disposal area and establishing an empirical relationship between moisture content/density of the material and its suitability for use as construction material. With time, the contractor will be able to quickly identify material suitable for dike construction.

<u>*Sand*</u>

During maintenance dredging, limited quantities of sands will be placed in the cells. The sands settle out quickly in the CDF and are concentrated in areas where the discharge pipes are placed. The areas with high sand concentrations tend to dry out quickly, and the material can be worked and handled after a very short drying period.

Based on the geotechnical data, it is anticipated that the new work material will contain significant volumes of sand. While sandy material has the advantage that it dries quickly and is easy to work, its use in dike construction is typically limited because of its high porosity, lack of ability to support vegetation, and erodibility. However, placed properly, the material can be used in dike construction in such a manner as to not impact the integrity of the dike. Specifically, the sand should placed in the core of the dikes or used along the interior of dikes constructed of finer grained material. All sections of the dikes constructed of sand should be covered with a layer of fine-grained material (approximately 2 feet) to limit the migration of water and also reduce erosion of the dike.

<u>Rock</u>

A considerable amount of rock is expected in the new work material. The rock will accumulate at the end of the pipe and may necessitate relocating the pipe frequently than for maintenance material. The rock can be used as pre-placed foundation material at the inboard toe of the dike to assist in raising the dike from elevation 30 to elevation 34 feet msl.

7.6.3 Generating Soils for dike Construction

Once the dredged material in a cell has dried to where equipment can be supported, producing dry soil for dike construction can begin. The production process is similar to a well thought out mining operation and will produce suitable material only at a certain rate governed by the elements. A check of those rates has determined that with proper attention and effort, sufficient dry soil can be produced for raising the dikes.

Areas of sand or other coarse grained material will dry rapidly, and it should be possible to work these areas almost immediately. However, the fine-grained material will take at least one drying season and possibly longer before it will be suitable for use. When the surface of this material reaches the moisture content where it can be worked, a dry, gray crust will form on the surface. In a period of a few weeks, the dryness will extend four to six inches down into the soil. The top layer of about three to four inches can then be skimmed off for use. The exposed soil will continue to dry through evaporation. The drying effort is quickly negated if good surface water runoff is not maintained.

7.6.4 Moving the Dried Dredged Material

The dredged material should be as dry as possible prior to movement. Excessive moisture in the material will make it difficult to handle and will increase transportation costs. Moving the soil by dump trucks or scrapers runs the risk of overloading the soil and causing severe rutting and slope failures. This is true not only in the cells but also on top of the dikes. In all cases, low ground contact equipment must be used. Experience by contractors working at the site has shown that 8-yard pans pulled by low-ground pressure tractors are very effective at moving the material on the site. While the size of the pans restricts the amount of material that can be moved, this type of equipment functions very well given the soil conditions at the site.

The types of soils being used are very sensitive to moisture content and will become slick and soft during even moderate rains. Therefore, the contractor should anticipate weather delays accordingly.

7.6.5 Placing the Dried Dredged Material

The material should be placed in the area of the dike to be raised and then spread and graded using a bulldozer. During the recent dike raises at the site, the fine-grained soils which comprise most of the embankments have been placed in thin lifts (8 to 12 inches) and "run in" using wheel loads from spreaders and dozers to provide compaction. The site has not used dedicated compaction equipment. Experience at the site has shown this approach to be acceptable. A formal compaction quality control program using ASTM methods is not recommended due to the nature of the material. The contractor, however, should ensure that there are no soft or areas of high moisture content in the placed material.

7.7 VEGETATION CONTROL

The conditions at the Eagle Island CDF are ideal for the common reed (*Phragmites*), and it has overtaken the entire site. *Phragmites* spread and colonize primarily through rhizomes that extend up to three feet into the soil and are difficult to eradicate. Historically, little has been done to control the growth of the *Phragmites* in the CDF. The thick stands of the plant in the CDF are thought by some to act as a natural filter that helps remove the sediments from the dredge slurry when the slurry is placed in the CDF during dredging operations. In addition, it has been speculated in published literature that the plants may assist in dewatering through the transpiration process in which the plants draw water from the soil through their root system and then release it through their leaves. Upon closer inspection, neither of these speculated benefits are being recognized at Eagle Island.

Conversely, the dense growths of *Phragmites* may significantly reduce the drying of the dredged material. The *Phragmites* shade the surface of the dredged material reducing the evaporative drying process which can be quite significant during the summer. Because of the reduced drying, the consolidation of the material is also reduced. In addition, when *Phragmites* are present, they tend to create preferential pathways through the CDF for the flow of the dredge slurry. The result is short-circuiting which can significantly reduce the efficiency of the disposal basin. Furthermore, the *Phragmites* can occupy a significant volume in the disposal area thereby reducing the volume available for dredged material.

Due to the potential detrimental effects the *Phragmites* can have on the overall function of the disposal basin, it is recommended that attempts be made to control the *Phragmites* in the cells. Many methods exist to control *Phragmites* including the use of herbicides, mowing, bulldozing, and burning.

One method that has proven effective in controlling the *Phragmites* in this type of setting is the use of the herbicide, Rodeo™, in combination with other control measures. The active ingredient in Rodeo™ is glyphosphate, which is widely used in a variety of herbicides. Rodeo™ is applied to the leaves of the plant typically with a sprayer. The Rodeo™ is absorbed through the leaves and translocated into the rhizomes. Once in the rhizomes, Rodeo™ prevents the plant from absorbing essential nutrients from the soil. Within 14-28 days the plant weakens and begins to die. Studies have shown that when used according to the manufacture's specifications, it is not a threat to soil, surface or groundwater, or aquatic or terrestrial invertebrates. These properties make Rodeo™ well suited for use in areas such as the Eagle Island CDF.

To successfully destroy the *Phragmites* in a 2-3 year period, the following steps are required:

1. The cell in which the *Phragmites* will be treated should be free of standing water and relatively dry.
2. The first application of the herbicide should be in the late summer/early fall when the *Phragmites* is fully-grown and seed dispersal is present. The stems should not be damaged during the spraying process because it will limit transport of the herbicide to the root system. Therefore, application by helicopter or airplane is recommended.
3. A second dose should be applied after the initial growth is killed and shoots begin to re-emerge. Usually the second dosage occurs 15-30 days after the first application.
4. During the late winter, the exposed rhizomes should be burned.
5. The process should be repeated for one to two more years as necessary.

The prescribed technique has been demonstrated to be effective at controlling *Phragmites* in large areas such as the Eagle Island CDF. It should be noted that the US army Corps of Engineers' Waterways Experimental Station is currently conducting research on the control of *Phragmites* through the use of alternative application techniques of herbicides. The results of this research may be useful in the control of *Phragmites* at Eagle Island.

7.8 MOSQUITO CONTROL

Removal of all areas of standing water within the CDF is crucial to controlling mosquito's at the site. This is accomplished through proper weir management and trenching of the area. Given that mosquito's begin breeding in early spring, it is imperative that the sites be dewatered as quickly as possible after dredging is completed. Even with aggressive dewatering, it is likely that areas will exist within the CDF that are conducive to mosquito breeding. In particular, the cracks in the crust typically hold some water and are well suited for mosquito breeding. Consequently, it is likely that use of insecticides will be required to control the mosquitoes. Due to the size of the cells and the difficulty in accessing some areas, aerial application of insecticide is recommended. Currently, the local county is responsible for mosquito control and should be consulted in planning an effective program.

7.9 EROSION CONTROL

7.9.1 Perimeter Dikes

The stability of the retaining dikes as related to the soil strengths and other geotechnical parameters has been discussed previously in Section 6. However, dike failures can be initiated by the effects of wind, rain, waves, and currents that cause deterioration of exterior and interior slopes. The exterior slopes of the CDF, which may periodically be exposed to extreme water levels and wave action, may possibly be subject to severe erosion.

Interior and exterior embankment slopes must be protected in two ways:

- by establishing vegetation on the slopes which will retard wind and water erosion; and,
- by periodic inspection and maintenance to address inevitable localized needs for embankment restoration.

7.9.2 Erosion Around Structures

Normal operations can cause erosion of interior dike slopes near the pipeline discharge and/or exterior slopes at the weir outlet structures. The pipeline discharge of dredged material is a powerful eroding agent, particularly if the flow is not dispersed. At the entrance to the weir, care must be taken to assure that erosion is not occurring around these structures and resuspending sediments.

7.10 MONITORING REQUIREMENTS

Successful long-term management of effluent water quality, dredge spoil consolidation, embankment stability and regulatory compliance will primarily include monitoring the following:

- effluent and runoff from the CDF, sampling for effluent quality and maintaining good

- records for the volumes and types of materials placed in the facility;
- records and documentation of efforts to establish and maintain a dried crust of dredge spoil atop all dredged materials; and
- monitoring of the stability of embankments as recommended in Section 5, and detailed in Volume II of this report.

The remainder of this section addresses the above requirements.

7.10.1 Sediment Quality

Sediments placed into the Eagle Island CDF should be periodically tested to determine if the sediments represent a possible source of environmental impact based on appropriate screening guidance's. Testing once every five years of representative samples of dredged material placed in the CDF should be sufficient.

Results of the analyses should be compared to historical analytical results and applicable sediment quality guidelines. If testing indicates a significant change in the concentration of a constituent of concern from historical levels or the concentration represents a potential source of environmental impact based on the appropriate regulatory guidance, additional testing and evaluation of the materials is recommended.

It is further recommended that all sediments from non-federal projects be tested using a similar protocol. Any materials with elevated concentrations of concern should be not be placed into the Eagle Island CDF as they will compromise the environmental integrity of the entire site.

7.10.2 Water and sediment levels within the CDF

During dredging operations, water levels and mud elevations within the cell receiving the dredge slurry should periodically be measured and recorded. This information will be very helpful in evaluating the accuracy of the model predictions used in the development of the management plan. The data can be used to optimize future analysis of the site.

7.10.3 CDF Discharge

The objective of the monitoring plan should be to provide documentation that effluent quality during filling and decanting operations meets State of North Carolina water quality criteria. Such documentation will also be vital to validate the adequacy of the disposal area design.

Parameters to be Monitored

Parameters to be monitored for a specific project involving placement of dredged material into the CDF should be chosen only after an analysis of all conditions relating to the project and the requirements set forth by the State of North Carolina. It is expected that effluent turbidity/suspended solids will be the only parameter that must be monitored.

Sampling Locations

Sampling must be conducted at the edge of the mixing zone to determine compliance with the State of North Carolina criteria. Upstream or background receiving water should always be sampled to determine ambient conditions. Sampling at the overflow weir will provide data on the adequacy of the site design and the accuracy of laboratory tests used for effluent quality prediction.

<u>Monitoring Frequency</u>

When the dredging operation commences, samples should be taken from the inlet pipe at approximately 12-hour intervals to verify design assumptions. Effluent quality samples should be taken periodically at approximately six hour intervals during the early stages of release to establish compliance and then at a rate of one sample per average hydraulic retention time.

Although water quality at the overflow weir is normally relatively stable, it can change very rapidly with changes in the weather. Therefore, samples should not be taken when the effluent from the disposal area is especially high in TSS for short periods because of high winds, hydraulic surges from the dredge, weir problems, or other transient events unless it is desired to document worst-case conditions.

7.10.4 Topography and Consolidation

Annual surveys of the entire CDF should be performed and should include repetitive surveys of specific cross-sections for comparison. This information will be useful in assessing the condition of the dikes and the amount of settlement and consolidation taking place at the site. In addition, the installation and monitoring of settlement plates at various locations inside the cells would provide information useful in assessing the consolidation of the material during the drying process.

7.10.5 Dike Monitoring

The dikes surrounding the cells should have scheduled periodic inspections to ensure their integrity. Inspections should look for areas of dike potential failure such as rotation, seepage, or erosion. All observations should be recorded and any concerns reported to the geotechnical engineer for the project. It is also recommended that the settlement monuments, inclinometers and piezometers be installed along the dikes to monitor their stability. In particular, this instrumentation should be used during periods of dike raises to ensure that the various assumptions made as part of the design process are appropriate.

7.11 RECORD KEEPING

All of the monitoring data collected for the site should be recorded and transferred into a centralized database for the site. In addition, detailed records of dredging activities such as volume, dredge periods, dredge equipment, and disposal locations should be maintained.

7.12 OPERATIONS MANUAL

To assist in the implementation of the findings of this study, an Operations Manual for the Eagle Island CDF has been developed and is provided as Attachment A. The document provides detailed guidance on the site operations, management, and monitoring and is intended to provide guidance for the day to day operations of the Eagle Island CDF. The manual is intended to be a working document, and all information contained within the manual, particularly dredging and dike raising schedules, should be reviewed on a yearly basis and updated as needed.

7.13 REVIEW AND UPDATE OF MANAGEMENT PLAN

The schedule of activities specified in this study plan was developed based on anticipated dredging schedules and dredge volumes. Numerous factors affect dredge schedules and volumes including weather, funding, availability of equipment, and variations in the dredge material. In addition, successfully drying the dredge material in the disposal area will directly impact the availability of material for dike raises. Due to the uncertainty associated with all of these factors, the management plan and schedule should be reviewed on a yearly basis to determine if adjustments are required.

For the current plan, review should focus on the following aspects of the dredging:

- The new work dredge schedule,
- Annual dredge volumes (new work and maintenance).
- The nature of the new work material (is it mostly sand that will dry quickly and be available for the major dike widening),
- Ponding depths required to meet the targeted water quality,
- The actual elevation of the mudline in each cell relative to the predicted elevation.

Based on the annual review, the District Engineer should adjust the management plan as needed. However, care should be taken to identify potential long-term impacts associated with the changes. In particular, changes in the cell where dredged material is to be placed or changes in the dike-raising schedule could have potentially significant long-term impacts.

8.0 CONCLUSIONS

The findings of this evaluation and their bases can be summarized as follows:

1. The estimated time frame under study is 20 years for the Eagle Island CDF. The volume of maintenance dredge material is projected to be about 1,000,000 cubic yards in a typical year when dredging of operational areas is performed. Over the 20 year period, approximately 30,500,000 cy of *in situ* dredge material will be placed in the Eagle Island CDF. This includes 24,500,000 cy of maintenance material and 6,000,000 cy of new work.
2. Maintenance dredging sediment is primarily fine-grained estuarine silt with some clay and fine sand. Sediment from the new work planned is expected to be a near equal mix of fines and sand/gravel.
3. The CDF is subdivided into three cells to facilitate dewatering and desiccation and to increase dredged material management options. For purposes of design, volumes in most years would be placed in one of the cells, with placement alternated between the three cells, allowing for at least a full one-year drying period. Operations for dewatering or material removal for beneficial use may continue while the alternate cell is used for a subsequent disposal operation. During years when new work dredging is occurring, material would be placed in two cells.
4. Construction of the dikes may be accomplished with conventional upland earthmoving equipment using onsite soils selectively removed from the site interior.
5. The total surface area available at Eagle Island site does not require diking to the ultimate 38-foot msl elevation in the initial phases of construction. A staged approach may be implemented.
6. The requirement for long term storage was evaluated with the PSDDF model and considered consolidation and drying. The *in situ* volume to be taken from the harbor and river is considerably more than the neat volume of the disposal area (23,441,000 cy), but the maintenance material *in situ* is unconsolidated. After consolidation, the volume of the dredged material will be less than the neat volume of the CDF. The results for the analyses show that at certain times the now-planned dike heights are not sufficient to retain the dredge slurry with adequate freeboard. However, studies have shown that the situation can easily be managed in the field to prevent overtopping.
7. An evaluation of the CDF discharge indicated the probable need for a mixing zone to meet State of North Carolina water quality standards for effluent during dredging operations.
8. After each filling operation, site "crust management" efforts should be concentrated on maximizing the containment storage capacity gained from continued drying and consolidation of dredged material and foundation soils. Once dredged material is placed in the site, a pro-active management program for dewatering should be implemented. This would consist of drainage by periphery and cross-trenching for dewatering enhancement, and removing the dewatered material from the area adjacent to the dikes for use in upgrading the dikes.
9. A monitoring program should be developed to comply with regulatory requirements and to operate the CDF effectively. The CDF monitoring program should be limited to sampling for effluent quality and maintaining good records for the volumes and types of materials placed in the facility.
10. A monitoring program should be implemented in accordance with recommendations herein to monitor embankment slope stability as the perimeter and interior dikes are raised.

9.0 REFERENCES

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(b) Dames & Moore, N.C 2000 (b). Draft Report, Embankment and Dredge Material Consolidation Analyses, Eagle Island Confined Disposal Site, Wilmington, North Carolina. September 2000

(c) Dames & Moore, N.C 2000 (b). Draft Report, Laboratory Testing, Eagle Island Confined Disposal Site, Wilmington, North Carolina. September 2000

(d) Program Documentation and User's Guide: PSDDF Primary Consolidation, Secondary Compression, and Desiccation of Dredged Fill by Timothy Stark, Department of Civil Engineering, University of Illinois at Urbana-Champaign, Urbana, Il. 61810. Provided as part of the PSDDF package in the ADDAMS software bundle provided by the U. S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, Ms.

(e) U.S. Army Corps of Engineers, Wilmington District. 1997. Dredged Material Management Plan (DMMP) Phase I Study, Wilmington Harbor, North Carolina, October 1997.

(f) U.S. Army Corps of Engineers, Wilmington District. 1989. Final Environmental Impact Statement, Long-Term Maintenance of Wilmington Harbor, North Carolina, Wilmington District, North Carolina, October 1989.

(g) United States Fish and Wildlife Service (USFWS) Endangered Species Website. February 2000. Information downloaded by Heather L. Berndt.

(h) North Carolina Natural Heritage Program Website (NCNHP). 2000. Information downloaded by Heather L. Berndt.

(i) U.S. Army Corps of Engineers, Wilmington District. 1996 b. Wetland Delineation for the Proposed North Cell Expansion at Eagle Island, March 1996.

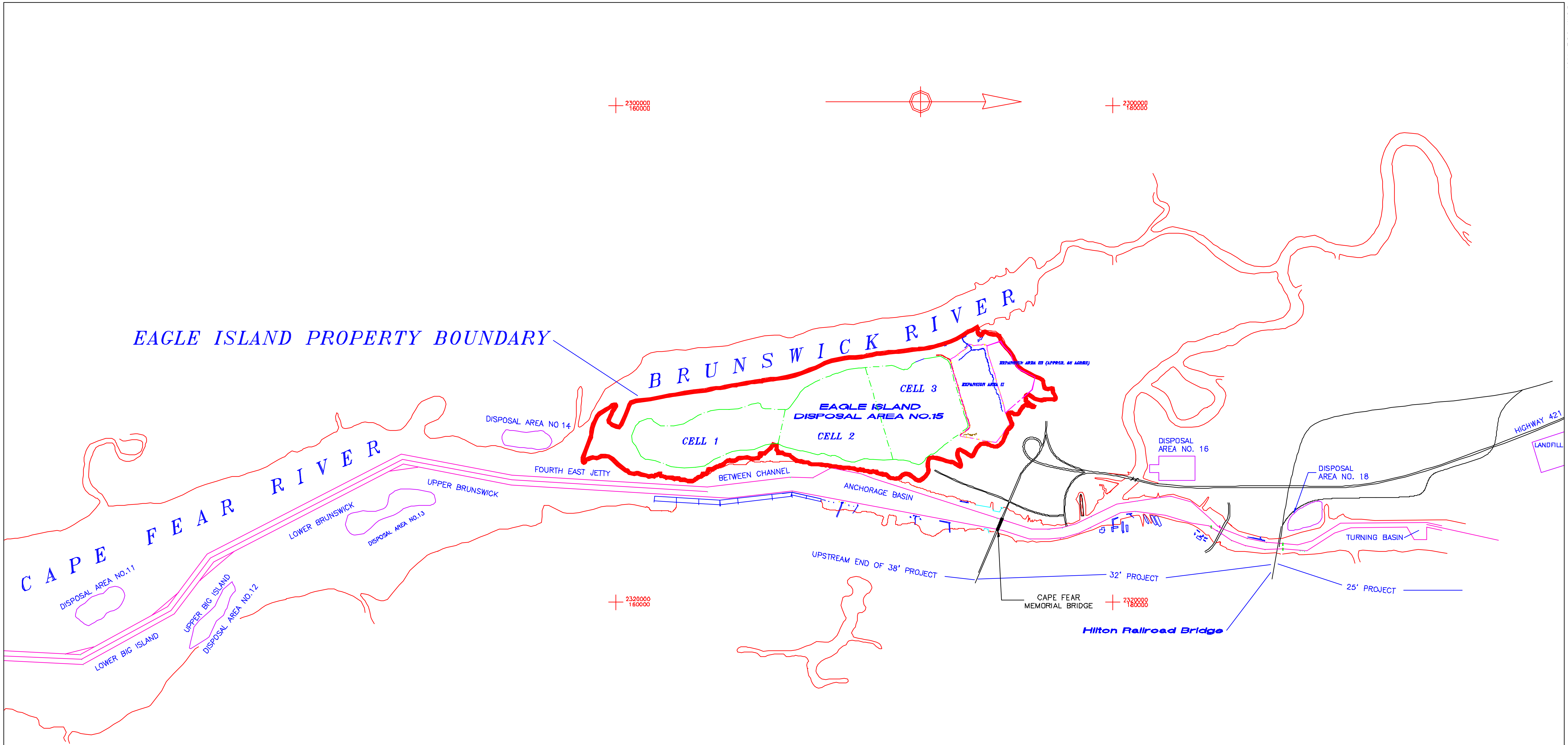
(j) U.S. Army Corps of Engineers, Wilmington District. 1996 a. Final Feasibility Report and Environmental Impact Statement, on Improvement of Navigation, Cape Fear-Northeast Cape Fear Rivers Comprehensive Study, Wilmington, North Carolina, June 1996.

(k) EA Engineering, Science and Technology, Inc. October 1996. Results of Chemical Analyses of Sediment Samples from Wilmington Harbor, North Carolina. Prepared for U.S. Army Corps of Engineers, Mobile District, Mobile, Alabama.

(l) National Weather Service Website. July 2000. Information downloaded by Kathy Jo Maples and Heather L. Berndt.

(m) U.S. Army Corps of Engineers, Wilmington District. 1995. Wilmington Harbor Field Trip Visit to Eagle Island Disposal Facility and Cape Fear River Orientation Trip, Wilmington District, North Carolina, August 1995.

(n) U. S. Army Corps of Engineers Engineering Manual (EM) 1110-2-5027, Confined Disposal of Dredged Material, 30 September 1987.



GRAPHIC SCALE

4000 0 2000 4000 8000 16000

(IN FEET)
1 inch = 4000ft.

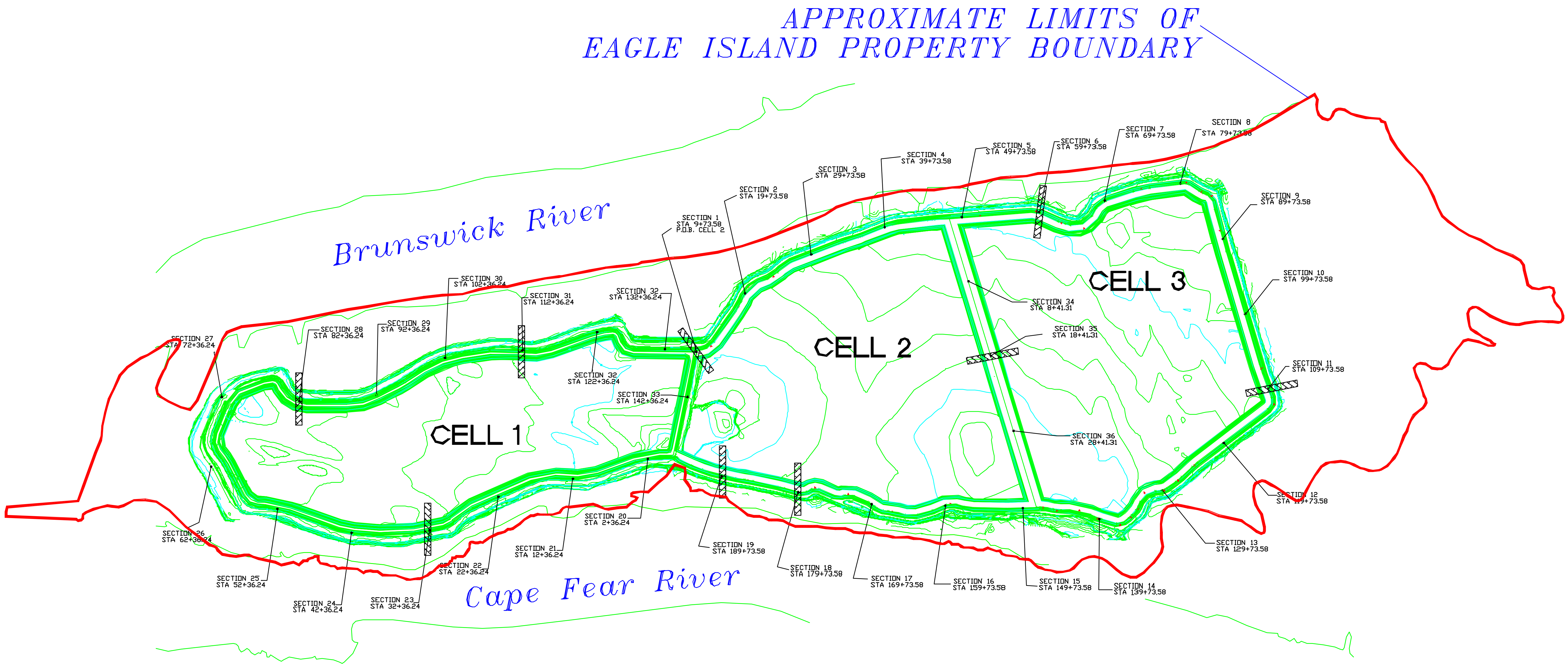
US ARMY CORPS OF ENGINEERS
WILMINGTON DISTRICT

TITLE:
PROJECT LOCATION MAP

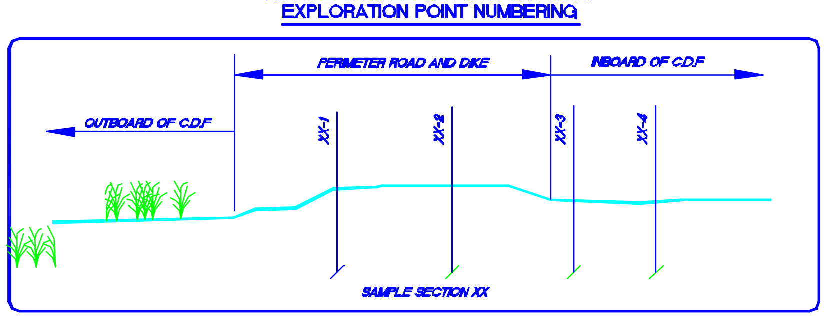
PROJECT:
EAGLE ISLAND MANAGEMENT PLAN

DATE:
MAY 2001

FIGURE 1



TYPICAL SAMPLE SECTION SHOWING
EXPLORATION POINT NUMBERING



NOTES

1. *"Section" identifies the location at which field (in-situ testing and soil borings) was undertaken.*
2. *"STA" refers to perimeter and cross dike stationing established by USACE.*

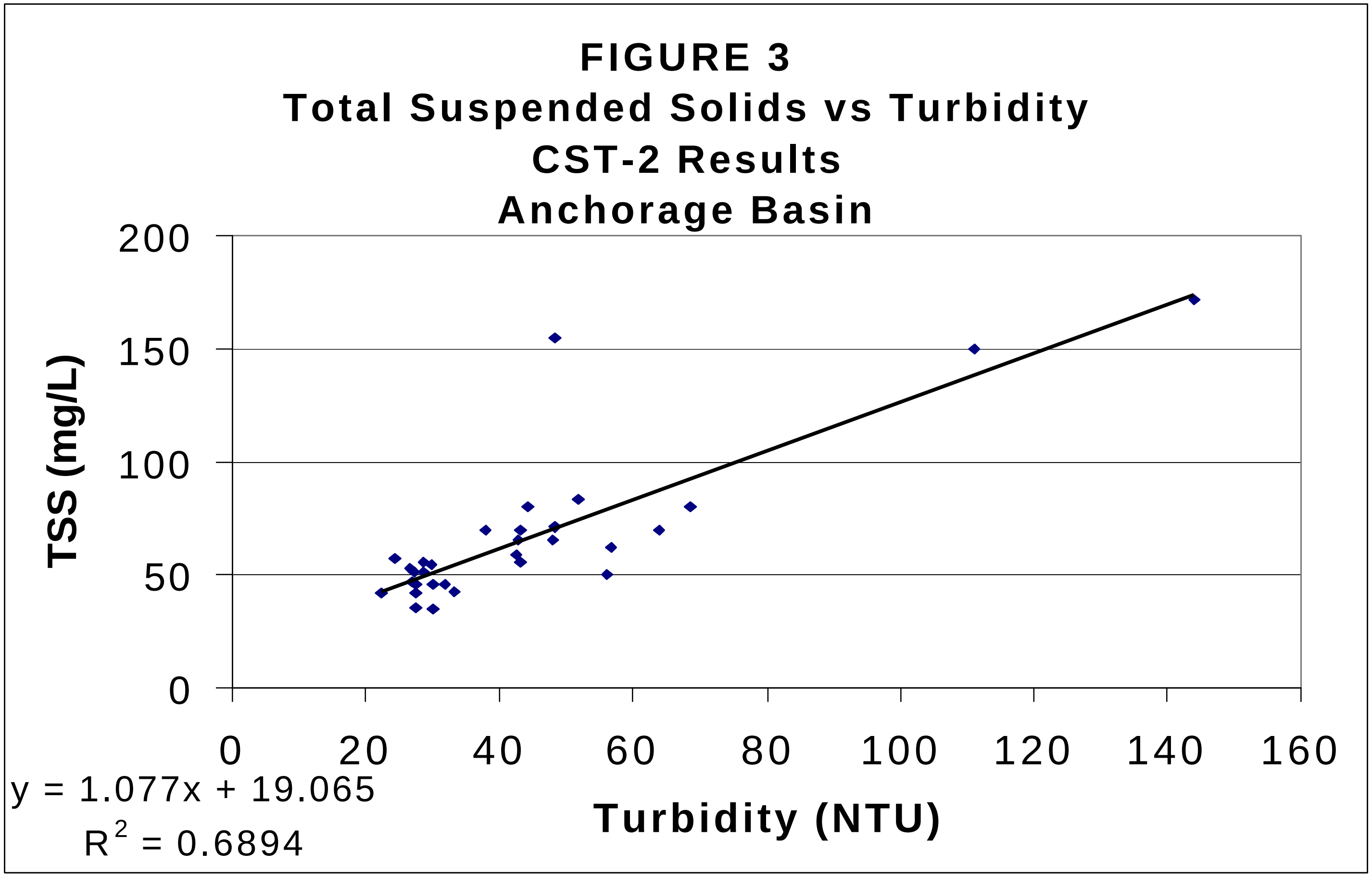
Indicates section at which detailed slope stability was undertaken.

GRAPHIC SCALE

N
NORTH

US ARMY CORPS OF ENGINEERS
WILMINGTON DISTRICT

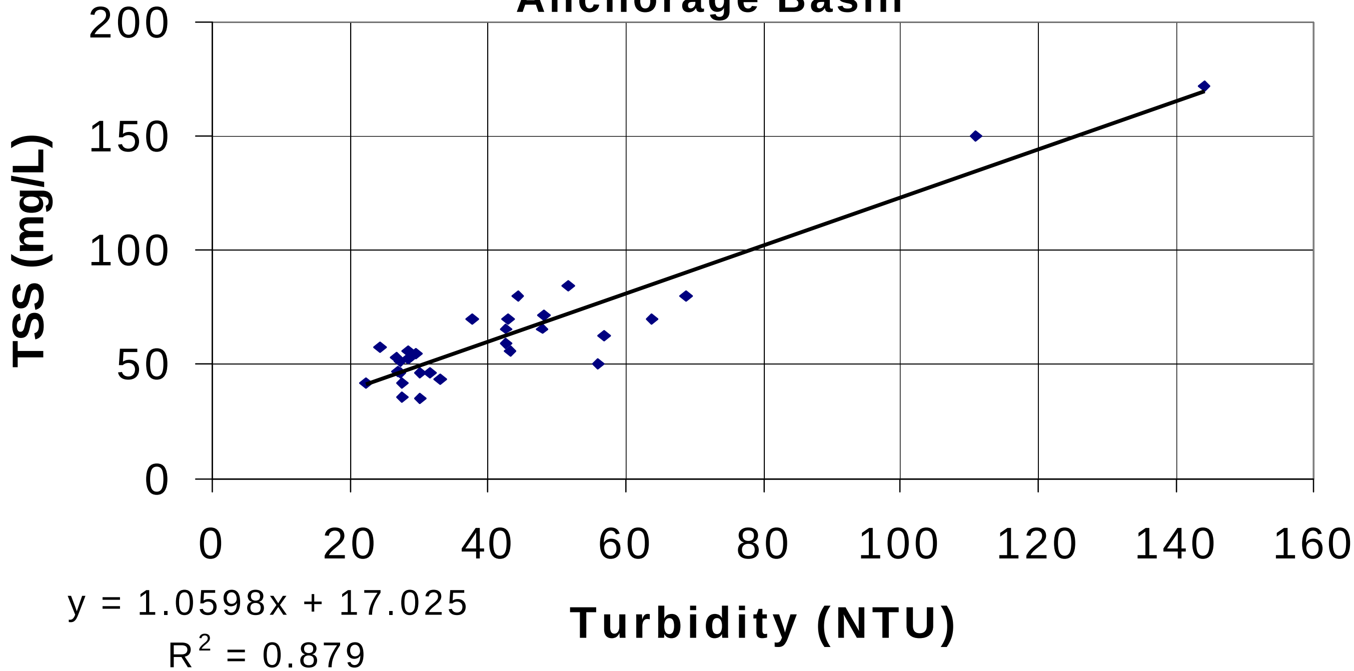
TITLE: PROPERTY BOUNDARY & INVESTIGATION STATIONING MAP	
PROJECT: EAGLE ISLAND MANAGEMENT PLAN	
DATE: MAY 2001	FIGURE 2



US ARMY CORPS OF ENGINEERS
WILMINGTON DISTRICT

TITLE:	TOTAL SUSPEND SOLIDS VS TURBIDITY CST–2 RESULTS ANCHORAGE BASIN
PROJECT:	EAGLE ISLAND MANAGEMENT PLAN
DATE: May 2001	Figure 3

FIGURE 4
Total Suspended Solids vs Turbidity
CST-2 Results
Anchorage Basin



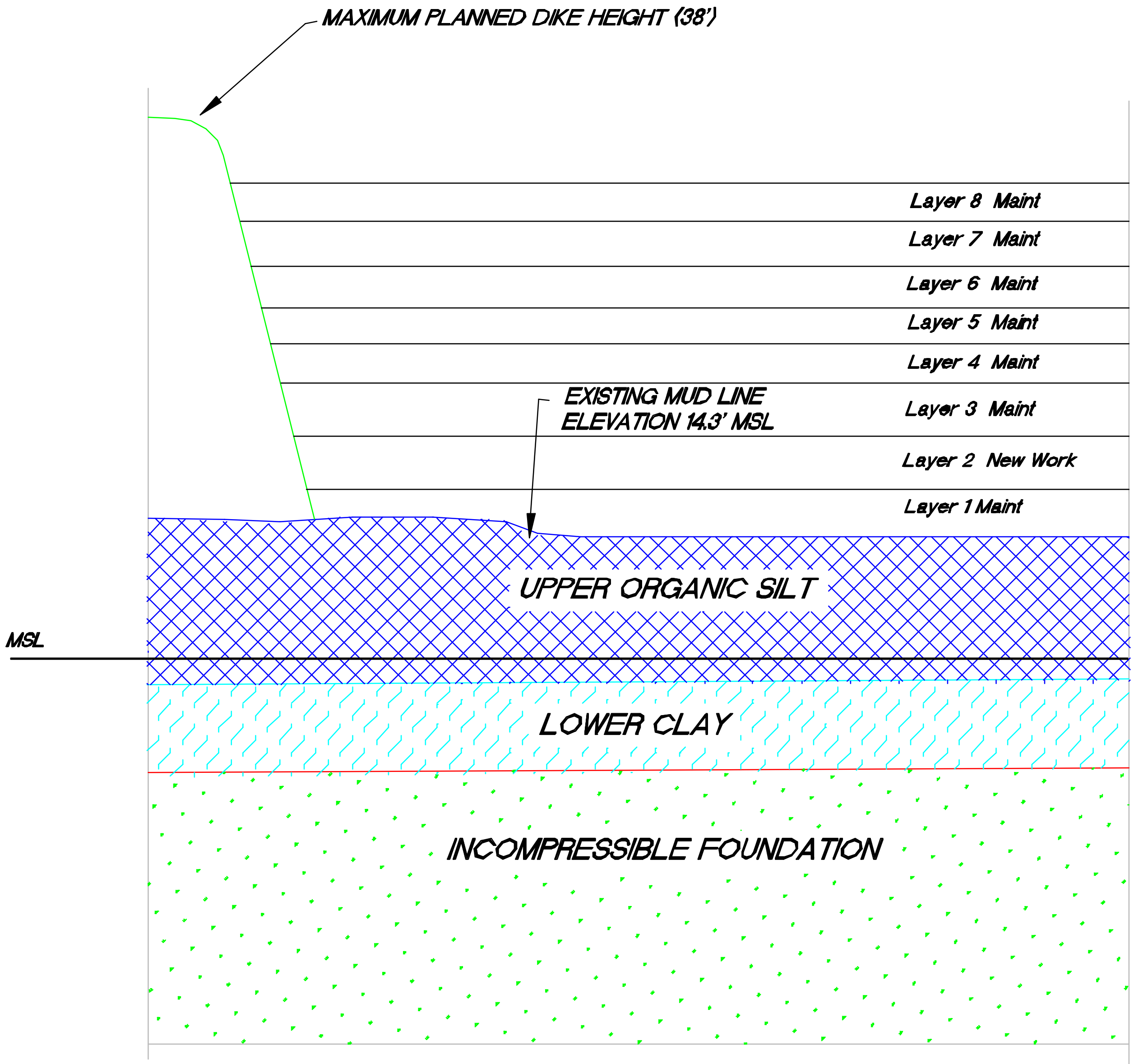
US ARMY CORPS OF ENGINEERS
WILMINGTON DISTRICT

TITLE:
REVISED – TOTAL SUSPEND SOLIDS VS TURBIDITY
CST–2 RESULTS ANCHORAGE BASIN

PROJECT:
EAGLE ISLAND MANAGEMENT PLAN

DATE:
May 2001

Figure 4



LEGEND

- SM, SP (Incompressible foundation)
- MH/OH (Upper Organic Silt)
- MH/CH/SP (Lower Clays w/ thin Sand Seams)

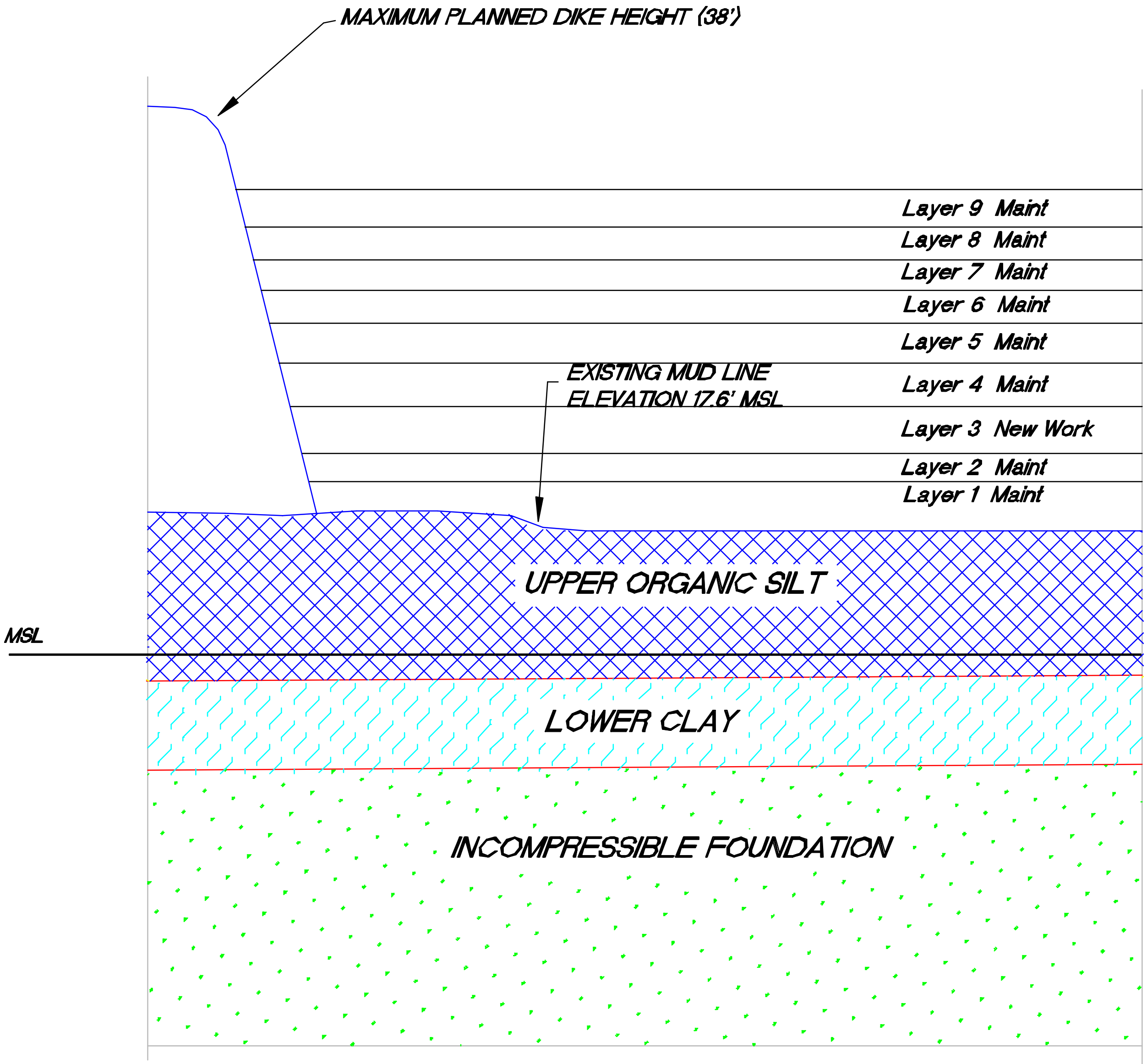
US ARMY CORPS OF ENGINEERS
WILMINGTON DISTRICT

TITLE: CROSS SECTION FOR CELL 1 FOR PSDDF SIMULATION

PROJECT: EAGLE ISLAND MANAGEMENT PLAN

DATE: May 2001

Figure 5



LEGEND

- = SM, SP (incompressible foundation)
- = MH/OH (Upper Organic Silt)
- = MH/CH/SP (Lower Clays w/ thin Sand Seams)

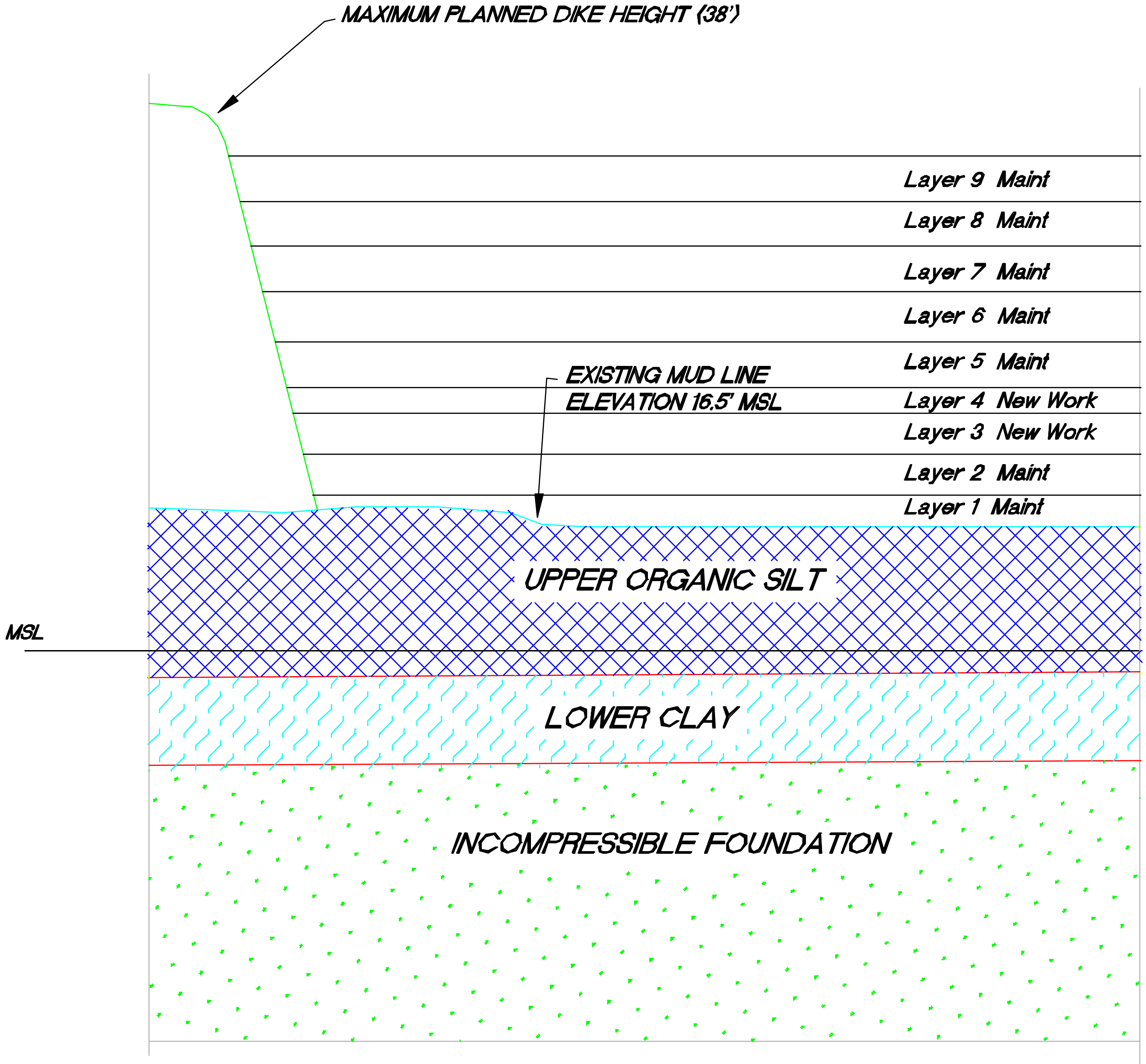
US ARMY CORPS OF ENGINEERS
WILMINGTON DISTRICT

TITLE: CROSS SECTION FOR CELL 2 FOR PSDDF SIMULATION

PROJECT: EAGLE ISLAND MANAGEMENT PLAN

DATE: May 2001

Figure 6



LEGEND

- = SM, SP (Incompressible foundation)
- = MH/OH (Upper Organic Silt)
- = MH/CH/SP (Lower Clays w/ thin Sand Seams)

US ARMY CORPS OF ENGINEERS
WILMINGTON DISTRICT

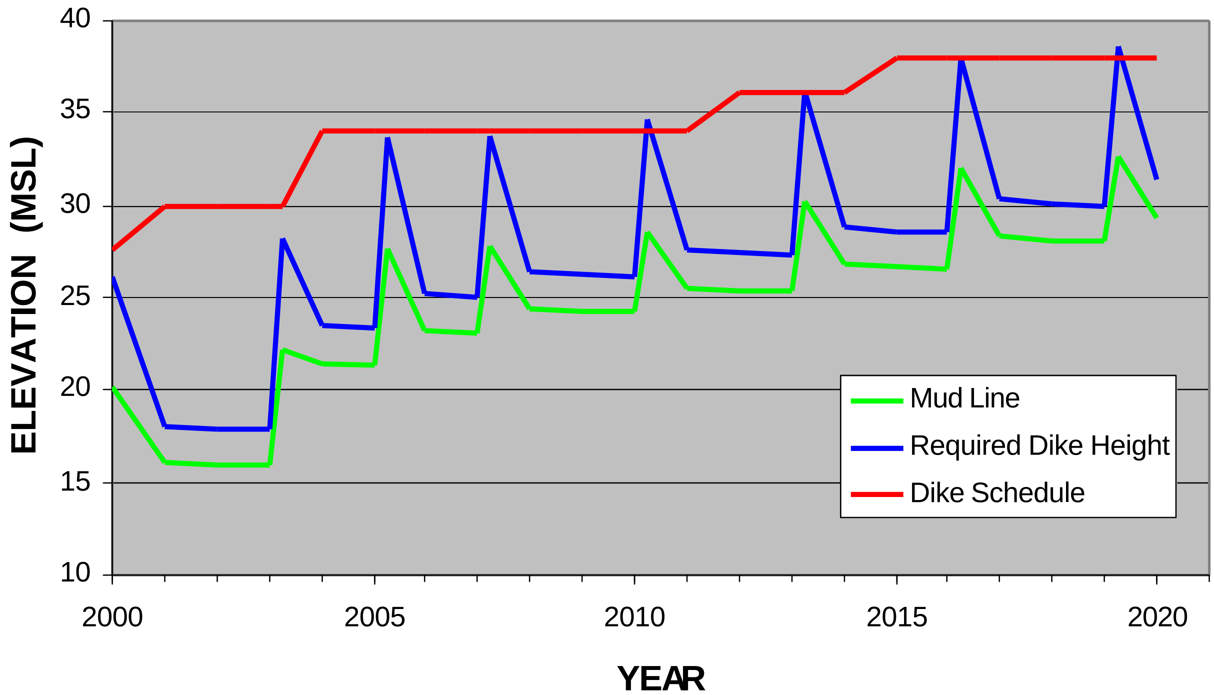
TITLE: CROSS SECTION FOR CELL 3 FOR PSDDF SIMULTATION

PROJECT: EAGLE ISLAND MANAGEMENT PLAN

DATE: May 2001

Figure 7

FIGURE 8 - EAGLE ISLAND CELL ONE



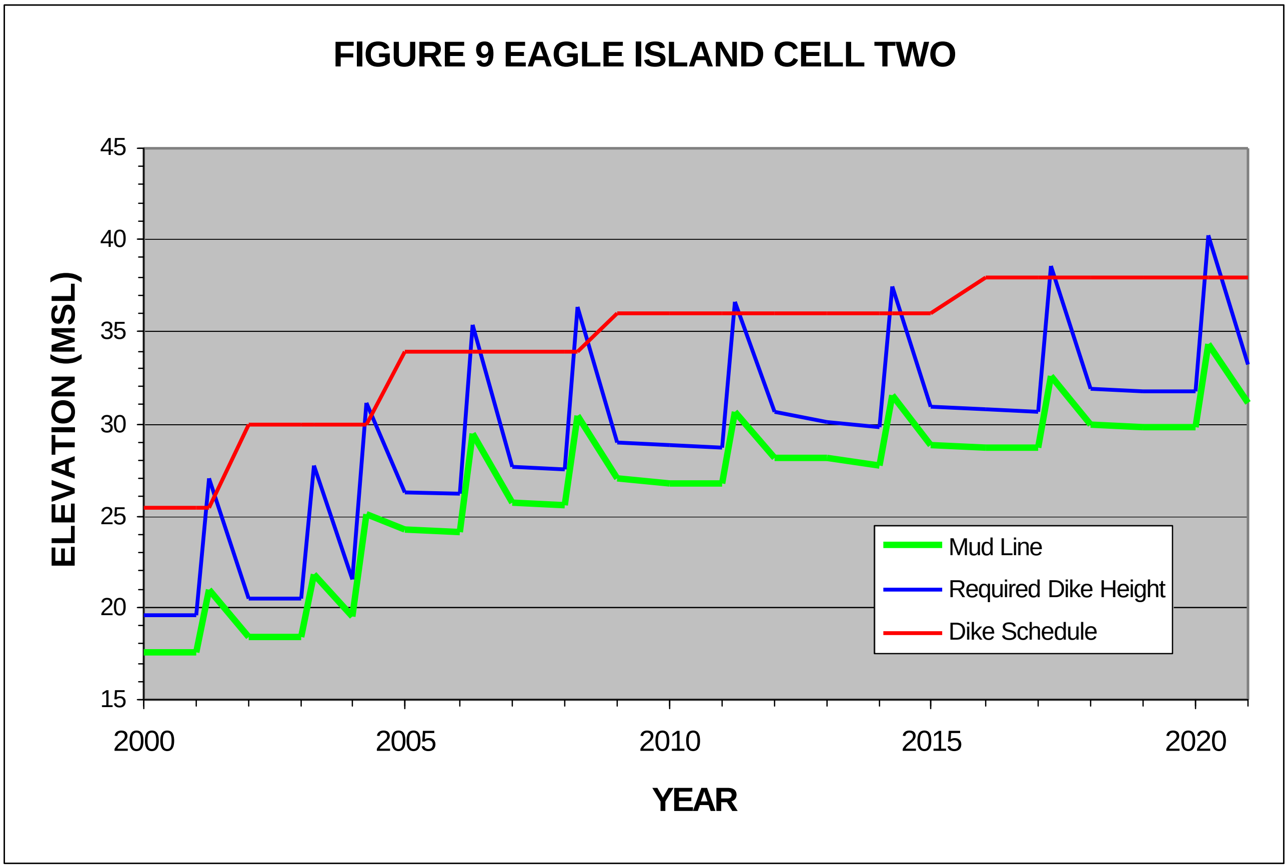
US ARMY CORPS OF ENGINEERS
WILMINGTON DISTRICT

TITLE:
RESULTS OF CELL 1 – PSDDF SIMULATION

PROJECT:
EAGLE ISLAND MANAGEMENT PLAN

DATE: May 2001

FIGURE 8



US ARMY CORPS OF ENGINEERS
WILMINGTON DISTRICT

TITLE:

RESULTS OF CELL 2 – PSDDF SIMULATION

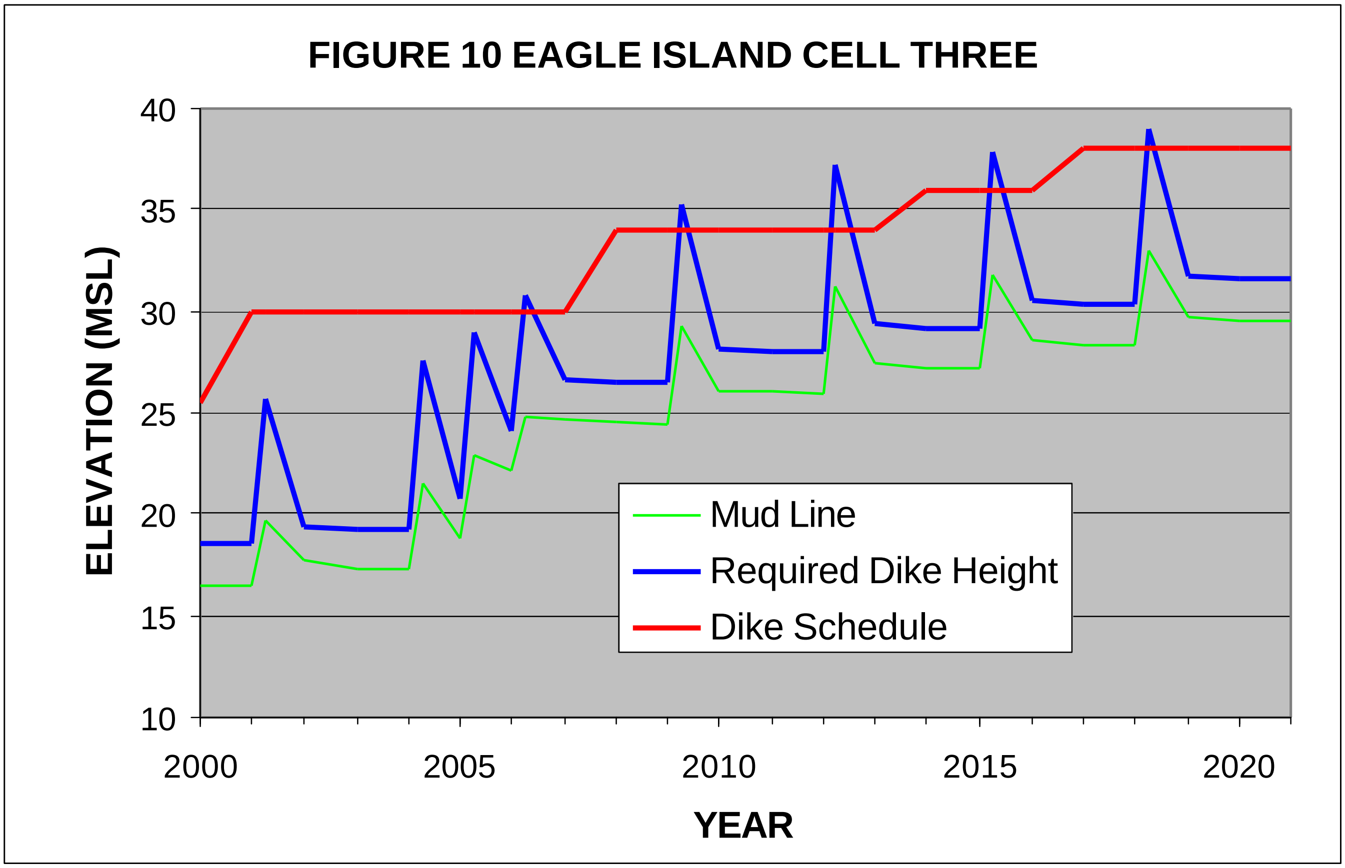
PROJECT:

EAGLE ISLAND MANAGEMENT PLAN

DATE:

May 2001

FIGURE 9



US ARMY CORPS OF ENGINEERS
WILMINGTON DISTRICT

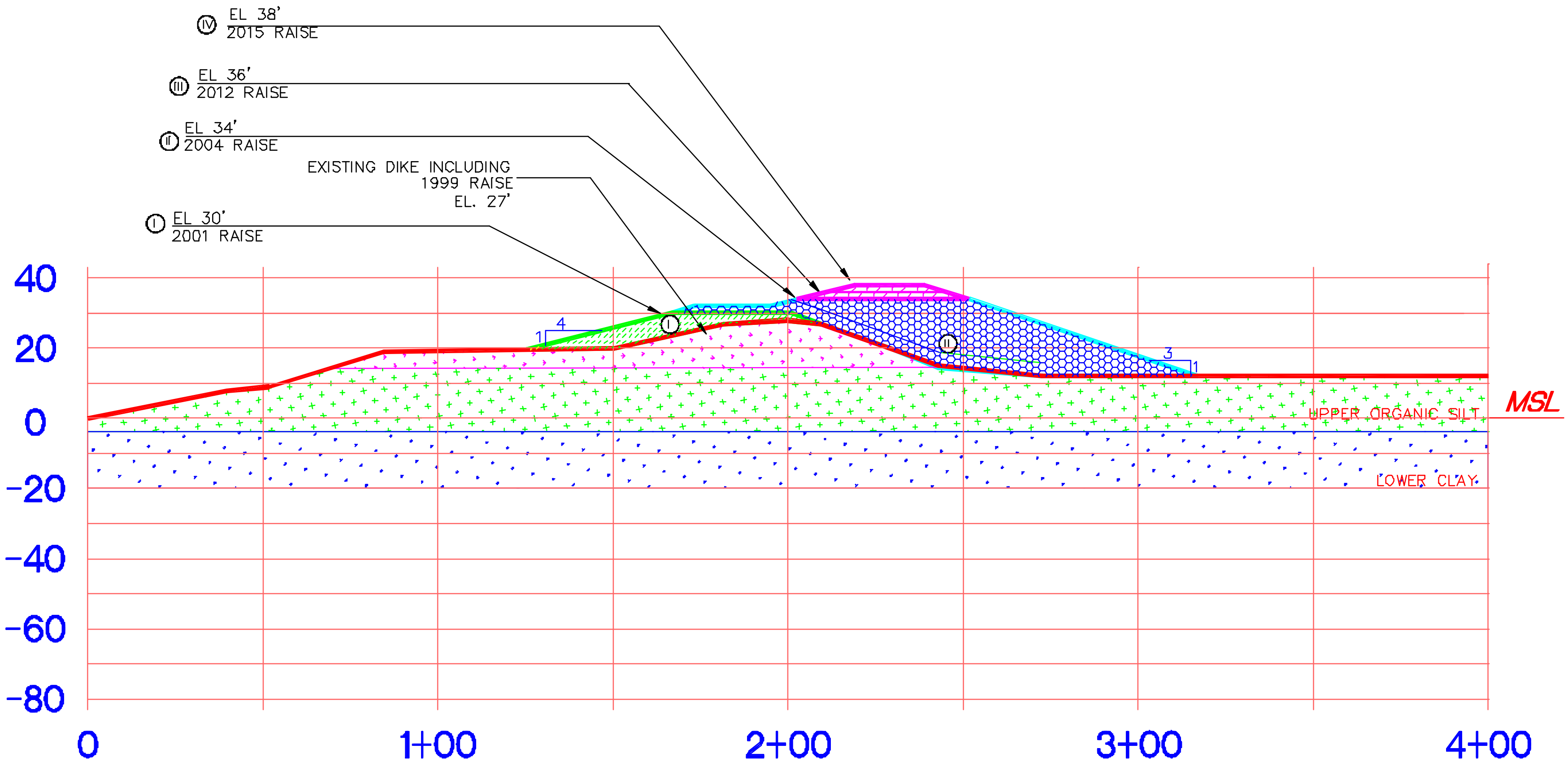
TITLE:

RESULTS OF CELL 3 – PSDDF SIMULATION

PROJECT:

EAGLE ISLAND MANAGEMENT PLAN

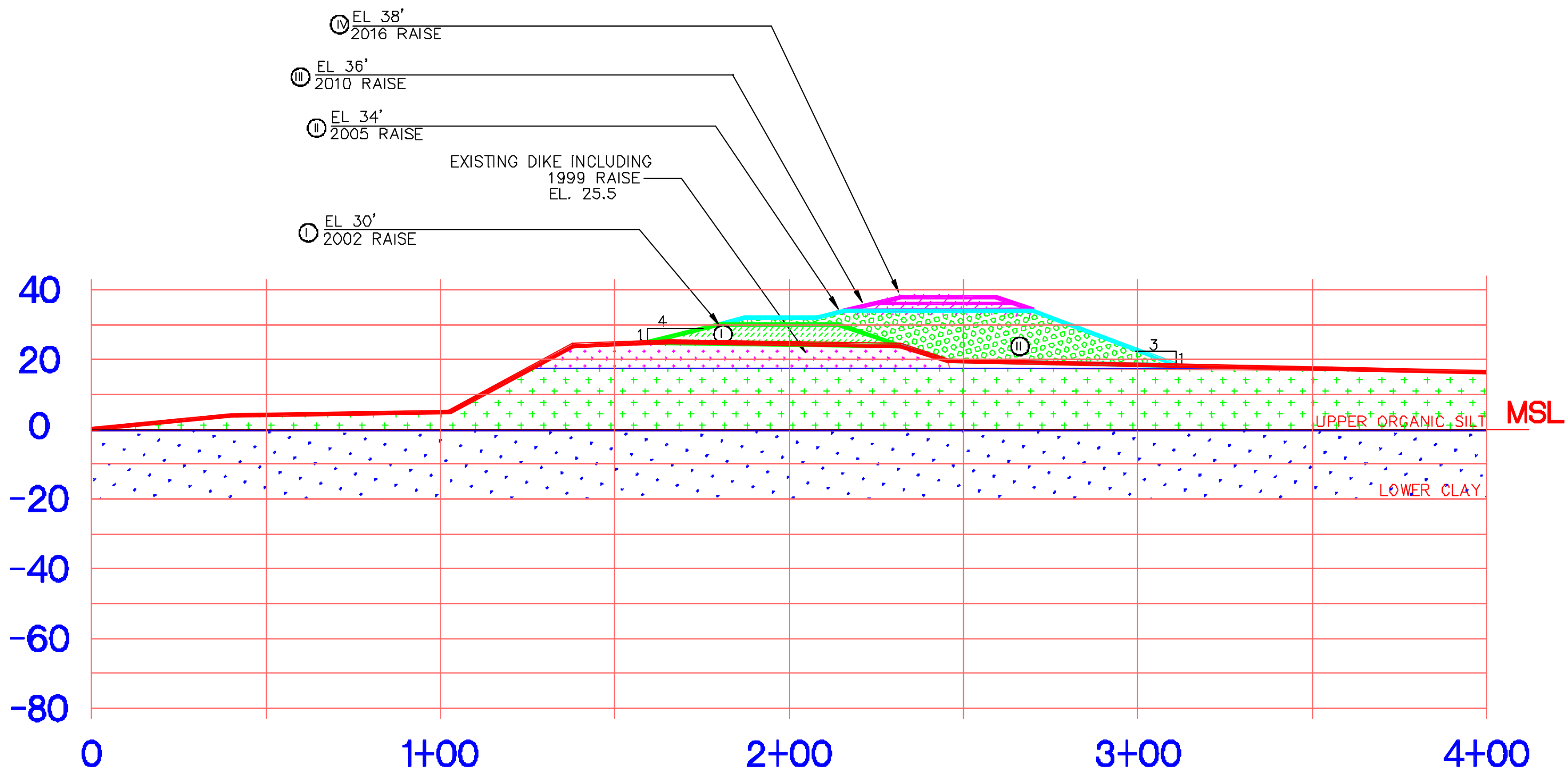
DATE: May 2001	FIGURE 10



SCALE: HORIZ 1"= 50' 0"
VERT 1"= 50' 0"

US ARMY CORPS OF ENGINEERS
WILMINGTON DISTRICT

TITLE: EVOLUTION OF CELL 1	
PROJECT: EAGLE ISLAND MANAGEMENT PLAN	
DATE: May 2001	Figure 11



SCALE: HORIZ 1"= 50' 0"
VERT 1"= 50' 0"

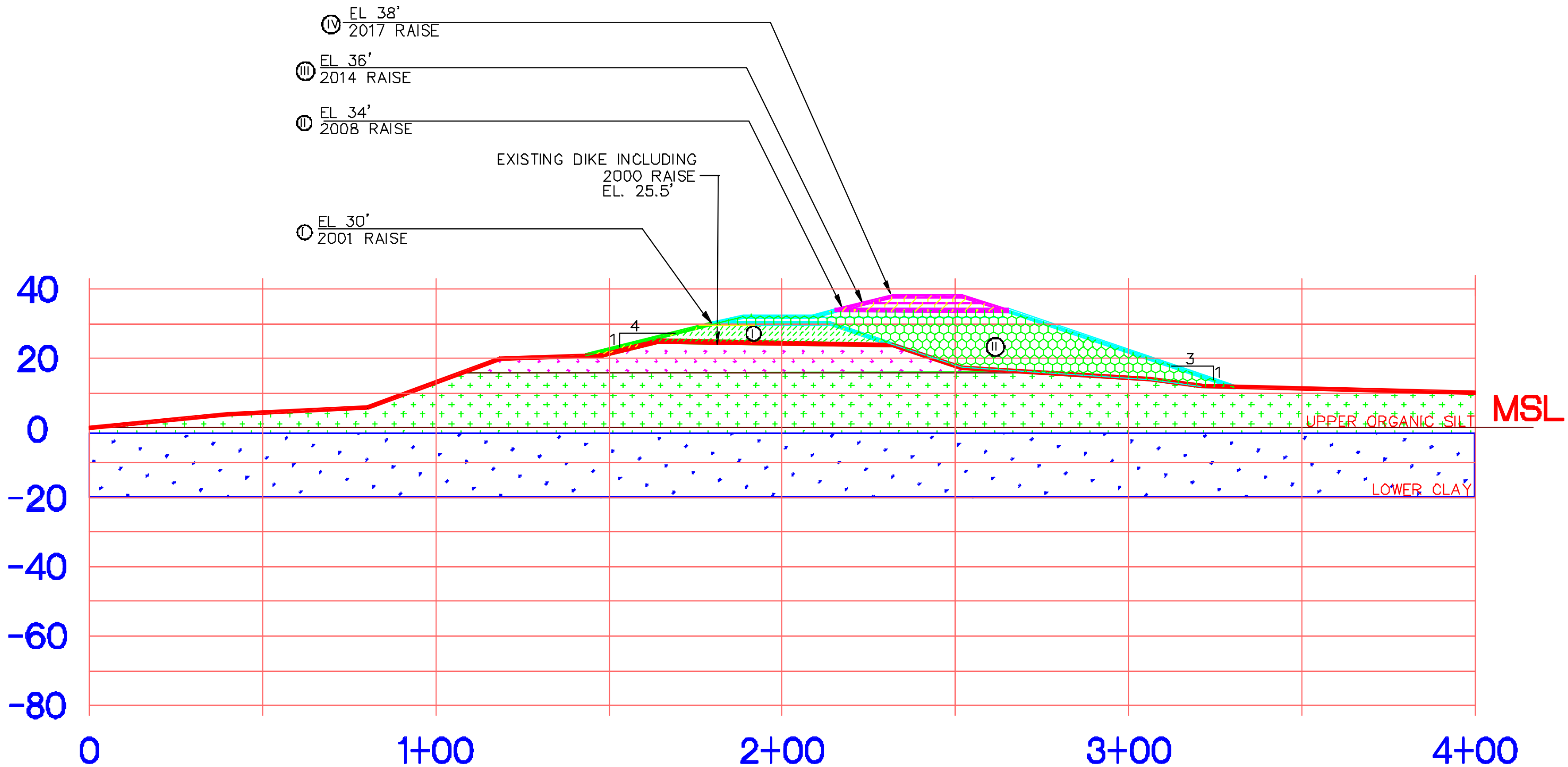
US ARMY CORPS OF ENGINEERS
WILMINGTON DISTRICT

TITLE: EVOLUTION OF CELL 2

PROJECT: EAGLE ISLAND MANAGEMENT PLAN

DATE: May 2001

Figure 12



SCALE: HORIZ 1"= 50' 0"
VERT 1"= 50' 0"

US ARMY CORPS OF ENGINEERS
WILMINGTON DISTRICT

TITLE: EVOLUTION OF CELL 3	
PROJECT: EAGLE ISLAND MANAGEMENT PLAN	
DATE: May 2001	Figure 13

END OF DOCUMENT

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